CAD TOOLS BASED ON AESTHETIC PROPERTIES

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Abstract:

The market success of industrial products strongly depends on their aesthetic appearance. Therefore a better understanding of customer wishes and response can improve the appreciation of new products. At the same time, the formalisation of the link between emotional reactions and products' basic geometric elements could enable the development of CAD tools that makes faster the achievement of the designer aims. A preliminary step toward this is the comprehension of the procedures designers follow to impress the desired character to the product. This includes the understanding of which elements and properties are evaluated and how are modified. In the paper we present some outcomes in this direction. They result from an analysis of the design activities carried out by stylists and surfacer(CAS/CAD operators) both in the automotive field (BMW, Pininfarina, Saab), and in household supplies field (Alessi and Eiger), done within the European Project FIORES-II (Character Preservation and Modelling in Aesthetic and Engineering Design). In particular, some of the identified aesthetic properties, used to judge the shape, and the operators acting on them are discussed.

Key words: industrial design, shape perception, geometric modelling

1 Introduction

The design of industrial products is a multidisciplinary activity that requires the collaboration of several experts whose aim is to achieve the best solution to the technological requirements and constraints while satisfying the original stylist's intent. The formalization of the relationships between shape and aesthetic character included in a computer system may help designers to obtain the desired effect more directly, and to maintain it during the different engineering phases. Such a formalisation 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. Several researches have been carried out to understand the existing link between emotional perception and shape, from different perspectives, including perceptual psychology [1], design and computer science [2-6]. The results show that this association is not a simple mapping: the same aesthetic parameters can be associated with different shape parameters. The fact that people perceive objects by comparing them to what they already know, thus depending on culture and experience, makes it almost impossible to give an absolute definition of an aesthetic character. On the other hand it seems preferable to specify how to increase or decrease the object's already given characters. In addition, it was shown that the classification of the aesthetic type strongly depends on some shape characteristics and properties, that are differently interpreted depending on the considered product. Therefore, an effective system needs to incorporate subject dependency possibly by introducing subject-specific relations or weighting functions. Based on these considerations, the European project FIORES-II (GRD1-1999-10785- Character Preservation and Modelling in Aesthetic and Engineering Design) [7]aims at building innovative CAD tools that adhere to the creative user mentality and at improving the cooperation between the main players involved in the product development process, by identifying shape properties directly affecting the aesthetic character, and by providing modelling tools for their evaluation and modification. In this paper some intermediate results of the FIORES-II project are illustrated.

2. Linking Geometry and Aesthetic

The definition of modelling tools that help CAS/CAD 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, requires at first the identification of 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. Within the project, 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 by using different means, which vary from internal documents, brochures and papers describing industrial products from an aesthetical point of view, to web questionnaires and to person-to-person video-recorded interviews carried out by psychologists. 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 to when they work with *surfacers* at the definition of the 3D digital model. In the former, the terms used have an emotional value (e.g. aggressive, elegant,..) whilst in the latter they provide an indication on which geometric elements and related shape properties have to be changed to obtain the desired effect. In fact, when stylists try to impress a specific character to a shape, they not only decompose curves in parts, but they also look at how the curve evolves within a certain area. In these cases, they normally talk about modifying certain properties of the curve itself, for instance *tension* or *acceleration* of a curve. The terms referring to these properties represent a 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 reached by understanding the procedures followed by designers and thus considering a two levels mapping: the first level links geometric properties with styling terms, the second links these to the emotional character. To identify the second association, FIORES-II is taking advantage of the "learning" capabilities of Case Based Reasoning (CBR) techniques [8-10]. CBR permits the dealing of the necessary large amount of data required to ensure the validity and the flexibility of the association, taking also into account the subject dependency.

3. CAD functionality based and acting on aesthetic properties

In the following we will concentrate on those terms that have been selected by the designers as being the most used for shape evaluation and modification requests. 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 relate geometric properties to perception and are mainly inherited from the traditional prototype creation by clay modelling [11]. The following terms have been selected for the prototype development:

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

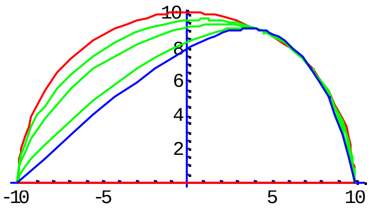
Currently the styling directives expressed in these terms are executed by *surfacers* who are able to translate them into the expected results throughout sequences of modelling operations, not directly linked to the target properties. This is only possible thanks to great skill both in modelling and in the adopted tools, but often requires a time-consuming trial-and-error loop. The objective is to develop modelling tools (called *modifiers*) that directly act on the modification of these properties, whose combination may allow an easier manipulation of a product character instead of working on low level geometric elements not directly linked with the target property. Modifiers act on several geometrical properties of a given curve at the same time. They can be considered as a semantic shape control. As previously stated, it turned out that these operators could also represent meaningful tools for shape comparison purposes. This 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*?
- Evaluation of a measure of the *modifier*.
- Specification of the mathematical function producing the expected shape modification and the related domain of application, i.e. hypothesis / restrictions on the curve 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 parameters can be used within the optimisation process and in which way.

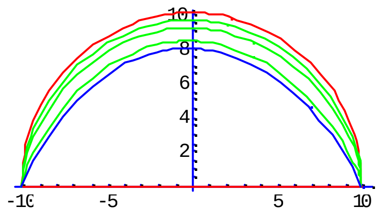
The above steps can be clarified by using the example of the *convex* modifier. Generally speaking, a curve is *convex/concave*, if the curvature along the curve has the same sign. In our case, it has a more specific meaning. From the interviews done to the end-users, it comes out that when designers are making a curve more convex, they are moving towards the semi-circle; i.e. considering the chord between the two extremes of a curve, the most convex curve on that chord in the user opinion is the semicircle with diameter equal to the chord (*ideal convex curve)*. Judging a curve more or less convex depends on several factors: the symmetry, the roundness, the curvature variation….. Many of these factors depend in turn on mathematical properties that can be calculated on the curve and compared to the corresponding values of the *ideal convex curve* in order to determine how much the curve is distant from the most possible convex curve. This is the semi-circle or an arc of circle if the constraints are compatible with, otherwise it is the curve satisfying the given continuity constraints at the extremities and presenting the lowest variation in curvature. A convexity measure criterion, which takes in account all the factors that are implicitly considered by the users, is obtained by measuring the distance of a vector of curve attributes from the corresponding vector computed on the *ideal convex curve*. To evaluate the vector distance it has been adopted the normalized Minkowsky measure, applied to a vector of values of selected properties of the curve and of the area (lamina), delimited by the curve and the corresponding chord. The main attributes considered meaningful for the convexity are:

- Length
- Area
- Coordinates of the gravity centre of the lamina
- Momentum of inertia of the lamina with respect to the axes of the coordinate system local to the curve

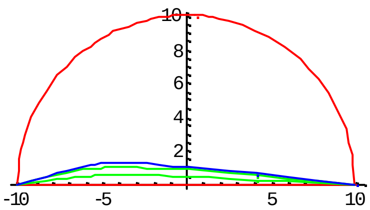
These properties have been recognised to provide good information regarding the key characteristics of convexity like roundness and symmetry. After the evaluations of the users feedback on several measure combinations, it emerged that attributes have different weights on the perception of convexity and in particular the most important ones seem to be curve symmetry and roundness. For that reason a vector of weights has been stated and used in the computation of the measure. Different values have been assigned to the vector of weights, in order to find measure values as close as possible both to the users expectations and discriminating between the different situations. In figure 1. some examples of the results obtained are shown. In the pictures, the Non_Convexity measure indicated is the one corresponding to the blue curve, i.e. the curve to be modified. The green curves are obtained making the curve more/less convex by considering G0 continuity conditions at the extremes.



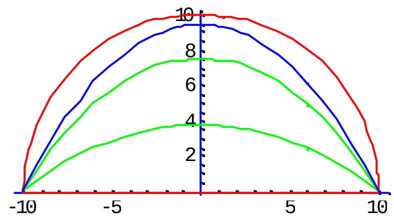
Non_Convexity measure = 2.37166



Non_Convexity measure = 2.1979



Non_Convexity measure = 5.92912



Non_Convexity measure = 0.916644I

Fig. 1 Examples of measured convex curves

Even if the test results are quite encouraging, the proposed measure to be used for evaluation needs to be further tested to be sure that it is really discriminatory. Anyway it has to be noticed that since it is given by a set of mathematical properties it can be further improved by including additional properties.
The function implemented to apply the *convex* modifier is based on the method to modify the original curve to tend to the most convex curve, or to the least convex one, e.g. the straight line, when possible, or it turns to use another modifier: *tension*. From the user point of view, to apply the modifier he/she has to chose:

- any planar curve (aesthetic property) of a shape on which the modifier will be applied,
- the preserving conditions at each boundary i.e. how much a curve extremity must be preserved (position, tangency or curvature),
- positive or negative increment, this parameter has a default value that the user can tune if necessary.

For each modifier, several difficulties have been encountered, mainly related to getting a full comprehension of how stylists perceive shape and to translating it 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 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 (characteristic curves), that 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 TM (thinkDesign is copyright of think3, www.think3.com).

4 Conclusions

In this paper, some of the results of the European Project FIORES-II have been described. They include the identification of two languages actually used during the product development by stylists and of their mutual relationships. 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.

Acknowledgements

This work is supported by the European Commission under the GROWTH Programme within the Project FIORES II, *Character Preservation and Modelling in Aesthetic and Engineering Design,* G1RD-CT-2000-00037.

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