Styling Properties and Features in Computer Aided Industrial Design

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ABSTRACT

Modelling tools supporting styling are currently being developed, taking into account a structured approach aiming at conserving the design intent during the whole product design process: this requires the storage of all the information necessary for recreating the model without losing any important characteristic. To this aim, it becomes crucial to study those elements of the model that may have a specific meaning directly connected to the design intent, i.e. styling features. The paper focuses on the definition and application of the feature concept for styling, mainly based on the research activities carried out within the framework of a Research and Development project supported by the European Commission named FIORES-II, which involved, beside many research Institutions from different European countries, a wide and direct participation of industrial application companies, such as Alessi, BMW, Pininfarina, SAAB, Formtech and Eiger.

Keywords: computer-aided styling, styling features, similarity.

1. INTRODUCTION

The increasing importance of aesthetic appearance in industrial products strengthens the needs of tools that better support stylists in expressing their aesthetic design intent and, once defined, in preserving it throughout the development process. Aiming at the objective of properly capturing and preserving the whole information necessary for recreating the model without losing any important characteristic, it becomes particularly important to study those components of the model that may have a specific meaning directly connected to the design intent, i.e. styling features.

Depending on the specific considered context, different feature definitions can be provided. Generally speaking features are "regions of interest". Their introduction allows the association of application data with a collection of geometric elements and facilitates context specific evaluations, e.g. selection of the appropriate manufacturing operations [1]. Well known are all kinds of mechanical features, which find their implementation mainly as parameterized macros in modern CAD systems. Unlike the mechanical environment, where parts are defined by canonical geometric shapes, in free-form modelling the association between shape and function is not easily identified and it is much more difficult to define a feature classification. Nevertheless, their utility in conceptual and detailed free-form design has been recognized [2] and some attempts to bring the feature concept into the free-form domain have been carried out [3,4]. The common limitation of these works is that they focus on a limited set of features, but the set has to be extended to provide full feature-based functionality. In this perspective, Fontana et al. [5] identified two categories of form features used in the different phases of computer assisted styling activity: structural features and detail features. Structural features include those lines defining the overall shape, e.g. contours, sections, character lines. Detail features correspond to local shape modifications for adding aesthetic and functional details. The authors mainly focus on the classification of detail features that is based on the topological and morphological characteristics associated to the deformations provided by the considered features. Pernot et al. [6,7] provided a further improvement of the above work using a mechanical approach to produce the feature deformation. Still referring to the previous taxonomy, Vergeest et al. [8] defined a parameter-based formalism: free-form features are formulated as a map from a parameter domain to a subset of the Euclidean space. All the above-described works are dealing with the shape creation but are hardly taking into account aesthetic information; only few consider aspects, such as brand character [9] or emotional feeling [10,11], but are very peculiar to specific products and not generally applicable. Defining a strict link between geometric characteristics and aesthetic features is not immediate due to the multitude of the possible shapes and to the fuzziness of the concept of aesthetics that can vary over the time and among cultures. In this context, we must understand which elements are meaningful both for the design and the style judgement: sometimes, *derived features* are more important for checking the aesthetic quality of the model than the constructive ones. In fact, stylists normally judge the aesthetic character of the product from the flow of certain lines that have no explicit representation in the product model, but can nevertheless be perceived, such as the lines originated by the reflection of the light on the object. Such lines are not belonging to the object model but are derived from it by calculations. Thus, they could be considered both as properties or as features of the model: on the one hand they reveal properties of the underlying surface (all surface points on the lines share the same geometric property, e.g. same angle between the normal to the surface and the light ray, but on the other hand they are feature lines with their own set of properties). We regard as *styling features* both derived and constructive elements as long as they are connected with the aesthetic impression of the object (in contrast to *engineering features*, which modify the shape for functional or technical reasons). They also carry information about the technical quality (e.g. surface continuity) but mainly about the aesthetics and sometimes-emotional character of the model. For pointing out the character of curves and surfaces, stylists usually use verbal descriptions for styling features: we will call this set of terms *styling properties*.

To exploit the potentiality of styling features both in modelling and evaluation phase, it is necessary to identify such characterizing styling properties, their mapping, if exists, to geometric properties, and the way to use this mapping for formal measurements. In Fig. 1 an attempt of feature classification meaningful for industrial design is summarized.

2. STYLING PROPERTIES

Designers usually concentrate their attention on properties that may have either a local nature or a more global behaviour. From practical experiments [12], it has been seen that stylists are more sensitive to the curvature characteristics of lines and surfaces than laypeople.

While laypeople identifies the most important points in the curves mainly as those corresponding to inflections and extension extremes (i.e. the highest and lowest or the most right and left points), stylists are more susceptible to inflections and curvature extremes.

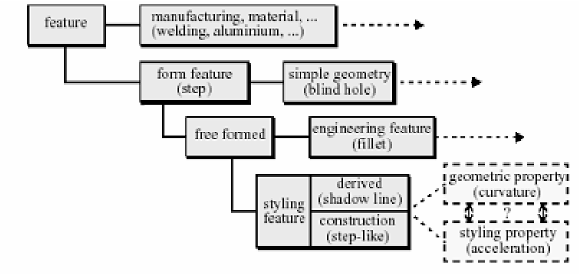


Fig. 1. Hierarchy of features and properties.

Stylists conceptually divide a curve into segments having *monotone curvature*. It has long been recognized that to have aesthetically good shapes, the number of extremes in the curvature distribution, and hence the number of separate segments with monotone curvature, should be the minimum required to meet the aesthetic intent of the designer [13]. At a first glance, many styling properties seem to depend directly on curvature properties, but although tests with curvature-dependent similarity functions [14] came up with reasonable results, they did not always suit the designers' thinking.

To understand which properties stylists consider, the design activities carried out in different industrial fields have been deeply analysed within the FIORES-II project [15]. In particular, the study focused on how stylists talk about styling properties for communicating their ideas. It emerged that they use different terms when speaking with marketing people or when working with CAS (Computer Aided Styling) operators 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. These second kind of terms are referred to those we call *styling properties* [16]. Currently the styling directives expressed in these terms are executed by CAS operators, which are able to translate them into the expected results throughout sequences of modelling operations, not directly linked with the target properties. This is possible only thanks to a great skill both in modelling and in the adopted tools, but often requires a time-consuming trial-and-error loop. Therefore, it is clear which advantages can be derived from exploiting the knowledge that is implicitly inside these terms through the definition of specific categories of styling features. 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. It is possible to say that there is something like a common language, which we called *Designer Language*. The language is not unique but allows describing changes to the model. Since generally people in the companies communicate in their native tongue, the identification of a common language required an agreement among the partners on the English translation based on proper words and definitions used by designers in their daily activity. The list is neither complete nor do stylists use all the identified concepts. Nevertheless, all stylists, designers, and model makers within the FIORES-II project agreed that the list was reasonable, even though they come from four different European countries and work in various styling applications like automotive and consumer appliance industries. Although styling is a very creative field of work, the few terms that follow are recognized as the most used to communicate design intent:

- Radius/Blending
- Straight/Flat
- Soft/Sharp
- Hard/Crude
- Convex/Concave
- Hollow
- S-Shaped
- Acceleration
- Tension
- Lead in
- Crown

To implement algorithms for the modification and analysis of the styling properties, the terms found have to be formally described and quantified; for each considered styling property we need:

- the definition of its meaning from the designer's point of view (i.e. what shape is the designer expecting when the property value changes for the considered entity);
- the identification of the geometric properties that are affected by the styling property;
- the setup and evaluation of a measure function;
- the specification of the mathematical function producing the expected shape modification and its related domain of application.

In this context there are several difficulties in fulfilling the above tasks, mainly related to getting a full comprehension on how stylists perceive shape and then to translate 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 the following for each term a description and a first proposal for its measurement are given which constitute the basis for the implementation in the software prototype. It must be noted that while it is in general impossible to generate a curve with a given specific property value, it is much more meaningful to modify an existing one by increasing/decreasing such a property.

2.1 Radius/Blending

In free-form modelling a *radius* normally indicates the one of the circle tangent to a specific point of the curve; it is mainly used to evaluate the *curvature* on a point along a curve. Stylists usually call 'engineering curves' or 'dead curves', those curves presenting areas of constant radius. An arc of circle is also called a 'true radius'. In styling, the term *radius* is much more generally used to indicate a somehow more rounded transition (a *blending*) between two curves or also surfaces. Fig. 2 shows different kinds of radius.

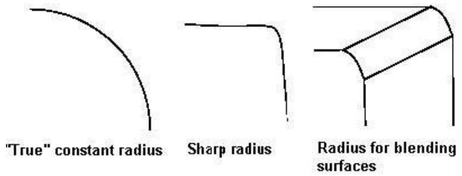


Fig.2. Examples of *radius*

The ambiguity of the term *radius* is a very good example for the difficulties in finding a unique language for communicating model properties. A meaningful measure for it should take into account the global appearance of the whole *blending* area. Therefore a suitable measure may be derived from the average of the curvature, evaluated along the considered curve (i.e. the tangential/turning angle)

$$radius = \left(\frac{1}{L}\int_0^L k(s)ds\right)^{-1} \qquad (1)$$

2.2 Straight/Flat

While in engineering a curve is either *straight* or not, for a stylist a curve can be more or less *straight*, depending on the dimension of the overall *radius* in relation to the curve length. The bigger the *radius* is, the *straighter* the curve. Even curves having inflection points and consequently variable radius can appear straight, as illustrated in Fig. 3. These curves are sometimes referred as *imperfect* when presenting one or few inflection points or *trembling* when having several inflection points. For surfaces, *flat* means more or less the same, and the formal connection between them is very close.

Surfaces can be called *flat* in one or two directions, if the sections along their principal directions (or large portions of them) are *straight* curves. Since *straightness* is perceived depending on the dimension of the curve, its measure should take in account such relation; thus a suitable measure can be given by the ratio of maximum and minimum curve elongation, which is the width and the height of the curve's encasing rectangle having minimum-area (see Fig. 3).

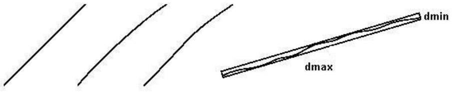


Fig.3. Examples of *straight* curves: engineering, styling, s-shaped, noisy (left to right)

In order to make the *straightness* range from 0 to 1 we use:

$$straightness = 1 - \frac{d_{\min}}{d_{\max}} \qquad (2)$$

Finally, in order to model the close inverse relation between *curved* and *straight,* we propose:

$$curviness = 1 - straightness = \frac{d_{\min}}{d_{\max}} \qquad (3)$$

2.3 Sharp/Soft

These terms are used to describe the properties of transition between curves or surfaces. In general, a small *radius* is called *sharp*, and a big *radius* referred as *soft*. Making a *radius softer* (*sharper*) can also mean to create a blending with G1 or G2 continuity instead of a G0 connection (and vice versa). The *sharpness* between surfaces/curves is due to the emergence of a visible edge/vertex on it, conversely the *softness* increases with the vanishing of the edge/vertex on it. These properties are sensitive versus the distance of observation, i.e. a *sharp* point can become smoother when looking at it more closely, as illustrated in Fig. 4. *Crisp* is another word for *sharp* that is especially used for characterising 90° edges and corners. Using the already given general measure for *radius* in Eqn. 1, the measure for *softness* considers the ratio of the *radius* and the length L of the measured curve. In this way, the shorter the curve the *softer* it looks with the same radius. Thus, we get:

$$softness = \frac{radius}{L} = \left(\int_0^L k(s)ds\right)^{-1} = \frac{1}{sharpness} \qquad (4)$$

2.4 Hard /Crude

Hard and *crude* are terms describing an abrupt change of curvature evolution in the transition between two curves/surfaces, or if they are connected only G0 continuously. We should set *hard* in relation to the context, because the *softer* environment of the transition, the *harder* we can call the same *sharp transition*.

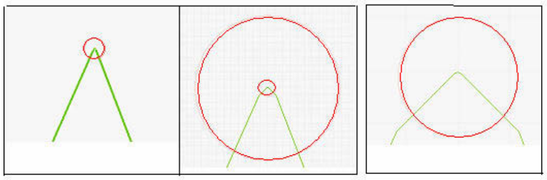


Fig. 4. *Softness* increases up to the fillet when the observation distance (circle) decreases.

Thus a reasonable measure seems:

$$hardness = sharpness\ (blending\ curve) \cdot softness\ (base\ curve) \qquad (5)$$

We always assume the connection between the base curve to the *blending* to be G2-continuous. Otherwise, any non G2-continuous *blending* is likely to appear *harder* than a continuous one (the bigger the curvature gap, the *harder*). This is especially true for non-G1-continuous *blending*.

2.5 Convex/Concave

Geometrically speaking a curve is said *convex* or *concave* if the curvature along the curve has the same sign. Whether a curve is convex or concave depends on the context in which the curve is viewed. Within closed contours or closed bodies the convex and concave curves and surfaces can easily be named as the ones bending to the outside or inside respectively. As the human perception tends to complete shapes, we can call a contour closed, if it bends more than 180°. If there is no body or closed contour to relate to, a curve is classified as concave or convex depending on the "natural viewing directions" which are from bottom to top and from left to right. If the curve follows these directions we can call it convex, otherwise concave.

When designers are making a curve more convex, they are moving towards the enclosing semi-circle; i.e. considering the chord between the two extremes of a curve (see Fig. 5), in the user opinion the most convex curve on that chord, is the semicircle with diameter equal to the chord(the yellow curve in the figure).

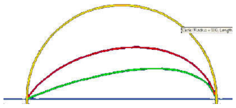


Fig.5. *Convex* curves

Thus the *ideal convex* curve is the semicircle or an arc of circle if the continuity constraints at the endpoints are compatible with, otherwise it is the curve presenting no inflection points and the lowest variation in curvature that satisfies the given continuity constraints. Judging a curve more or less convex depends on several factors: above all the symmetry, the roundness and the curvature variation. Many of these factors depend in turn on mathematical properties that can be calculated on the curve. The convexity measure criterion, which we propose, takes in account all the factors that are implicitly considered by the users, and it is obtained by measuring the distance of the vector of curve properties from the corresponding vector computed on the *ideal convex curve*. It has been adopted the normalized Minkowsky distance, 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, namely: length, area, gravity centre coordinates and momentum of inertia. Let $\mathbf{V}^C = \{v_i^C\}$ the vector of property values of the curve and $\mathbf{V}^Q = \{v_i^Q\}$ the vector of property values of the *ideal convex curve*: the *non_convexity* measure is given by

$$\sum_{i=1}^{k} w_i \frac{\left| v_i^C - v_i^Q \right|}{D_i} \qquad (6)$$

The maximum of convexity is then given by a *non_convexity* measure value equal to zero. The normalization factor D_i is necessary to guarantee that homogeneously scaled curves present the same measure; we use the values of the properties evaluated for the correspondent semicircle in the case of the length, area, y component of the centre of gravity, momentum of inertia with respect to the x-axis, momentum of inertia with respect to the y-axis. While for the x component of the centre of gravity we use the radius. The factor w_i is the weight of the ith attribute. Weights have been added since it has been experimented that the considered attributes have different impact on the perception of convexity and in particular the most important ones seem to be curve symmetry and roundness, provided by the gravity centre coordinates and by the momentum of inertia respectively. If we consider a local coordinate system associated to the curve under examination, having the x axis coincident with the chord, the origin positioned at the middle point of the chord, the curve symmetry is related to the position of the point of maximum elevation with respect to the y axis: the closer the point is the more convex the curve is. Whereas the roundness is bigger as smaller is the difference between the values of the radius of the enclosing semicircle and that of the curvature at each point. For concavity we can simply consider:

$$non\_concavity = -\,non\_convexity. \qquad (7)$$

2.6 Hollow

A property very close to *convexity* is *hollowness,* which is a less technical but more qualitative, and consequently subjective, concept. From the engineering point of view, a curve or surface can be called *hollow* if it is *concave*. In styling, a curve or surface can look *hollow* by wish or by mistake although it is not *concave* at all (see Fig. 6).

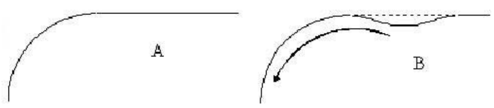


Fig.6. Example of *hollowness* (B).

If for example an almost *straight* curve is connected to a rather small true *radius*, the connection usually appears *hollow*. The observer tends to follow the *radius* tendency with his/her eyes that would create a truly *concave* transition. To give a measure for *hollowness*, it seems to be necessary to involve the curve's direction and length, as long horizontal lines are often judged as being *hollow*. To avoid such effect normally the straight curve is made a little bit convex and the connection with the radius starts before. This is what is done in the automotive design when defining the section of the car roof. We can use for stand-alone curve:

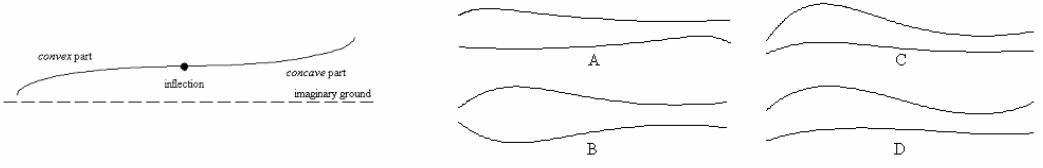
$$hollowness = concavity \cdot curve\ length \cdot horizontality \qquad (8)$$

where *horizontality* is a function which gives high values for a direction close to horizontal, as the cosine of the elevation angle □ for the whole curve (e.g. the connection line between start and end point) with the x-axis. The examples provided by the designers are always indicating horizontal lines but we are not able to exclude that the same can apply to vertical lines connected to radius as well, but further verification are necessary.

2.7 S-shaped

An *s-shaped* curve consists of two parts of opposite curvature sign, i.e. it consists of a *convex* and a *concave* part that are separated by an inflection point (see Fig. 7(a)). In general, in the automotive sector, *s-shaped* curves are not wanted, because the inflection point is a very outstanding curve feature that may disturb the overall look. If an *s-shaped* curve is wanted, then the *S* should be well visible.

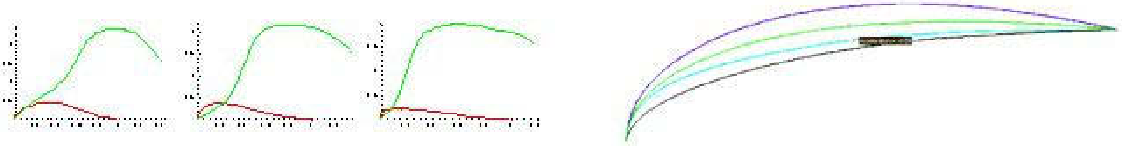
Curves with an inflection but a weak visibility of the *S* are mostly regarded as being bad. The property of being *s-shaped* is first of all a binary valued measure (*true/false*). An *s-shaped* curve is characterised by additional properties (see Fig. 7(b)): *biasing orientation*, *tendency* and *visibility*.



(a)

(b) left/right-biased (A), convex/concave tendency (B), well/hardly visible (C & D)

Fig. 7. *S-shaped* curves



(a)

(a) Examples of curves with *acceleration with their corresponding curvature plot (the upper curves in green)*

(b)

(b) Curves with increasing acceleration (from the top to the bottom)

Fig. 8 *Accelerated* curved

To indicate whether a curve is *biased* (left or right), the normalised arc length position *s* of the inflection point within the curve can be used:

$$biased = (2 \cdot s_{inflection} \,/\, L) - 1 \qquad (9)$$

Tendency indicates which is the dominant characteristic:

$$tendency = convexity(convex\ part) + concavity\ (concave\ part) \qquad (10)$$

Visibility combines *curviness* (to express whether the 'S' is well recognisable or quite hidden) with the *biased* property (because the inflection is less well recognisable if it appears close to the end points of the curve):

$$visibility = curviness \cdot (1 - biased^{2}) \qquad (11)$$

2.8 Acceleration

A curve without any *acceleration* is a *straight* line or a true radius. If curvature changes too slowly, the curve may show no *acceleration* at all. *Acceleration* is sensitive to the orientation of the curve on which it applies. There is no unique definition at which point a curve starts to accelerate, but *acceleration* always starts in a rather *flat* area and leads into a high curvature region; moreover stylists say that symmetrical curves have no *acceleration*. Considering this styling property as a local property, it coincides with the differential geometry definition; therefore we may define a measure for *acceleration* in a region between *s*1 and *s*2 by the ratio of curvature difference Δk and the arc length difference Δs :

$$acceleration_{s1,s2} = \frac{(k(s_2) - k(s_1))}{(s_2 - s_1)} \qquad (12)$$

The degree of *acceleration* in one point can then just be given by the rate of curvature change. The higher is the change, the more *acceleration*.

But considering the whole curve, the *acceleration* is related to how much the variation of the tangent to the curve is balanced along it. Thus a curve is said accelerated around an end point when the variation of the tangent is bigger when moving toward that point. The closer the variation is to the end point the more the *acceleration*. Then we propose: given i ∈ [0,n] $k(\bar{s}_i)$ local maxima of *k(s)* s ∈ [0, L]

$$globalAcceleration = \frac{1}{n}\sum_{i=0}^{n}\left(\frac{\bar{s}_i}{L} - 0{,}5\right)\cdot\frac{k(\bar{s}_i)}{\int_c k(s)ds} \qquad (13)$$

The above measure considers that the presence of several local curvature maxima doesn't increase the *acceleration* effect; on the contrary, if the curvature maxima are distributed along the curve, the curve results not accelerated. In Fig. 8(a) the three curves (in red) with increasing acceleration from left to right are shown together with their correspondent tangent variation (i.e. curvature) curves. Finally in Fig 8(b) additional examples of top-down more accelerated curves under the same boundary constraints are given.

2.9 Tension

Tension can be understood from the physical analogy of applying *tension* to a steel spline. In the physical example the highest *tension* (or the bending energy) can be found where the curvature is highest. Stylists say that straight lines have either no tension or an infinite one. Many designers said that one could feel *tension* only if 'something happens' in the curve, which means that there is an evolution of curvature along the curve. This is probably the more debatable among the emerged styling properties; in Fig. 9 it is illustrated how tension is perceived from the interviewed end users: the curves depicted below are judged with an increment of tension from top curve to the bottom one. Taking in account that it is meaningful to evaluate this property only on rather straight parts of the curve, we propose the following measure that put the curvature difference in relation to the average curvature (in Eqn. 14 indicated as k_{avg}):

$$tension = straightnessOfMeasuredPart \cdot \frac{(k_{\max} - k_{\min})}{k_{avg}} \quad (14)$$

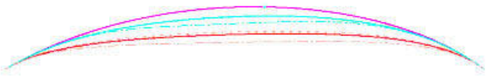


Fig. 9. Example of curves with *tension* increasing top-down

2.10 Lead in

To better understand the term *lead in*, it is useful to know how clay modellers proceed in their work [17]. To connect two surfaces at first they use a constant radius which in most cases connects only G1-continuously; this *hard* connection between the two main surfaces does not lead well into the transition. The blending curve or surface needs to be smoothly lead into the *radius* in order to look harmonic. Similarly when working on the CAD model a *lead in* indicates the transition of the main curve (or surface) to a *radius*. Designers say that a *lead in* prepares the eye to what follows. A good *lead in* is not a true radius but a free-form curve and connects to the curve at least G2-continuously. A curve *lead in* can be seen as conceptually composed by two parts, which smoothly join the main curves and are accelerating toward the common point. In order to achieve this, it is possible to act on the common point, but more frequently it is necessary to have more space or a longer curve: to this aim part of the curve has to be cut away to allow the blending to start earlier.

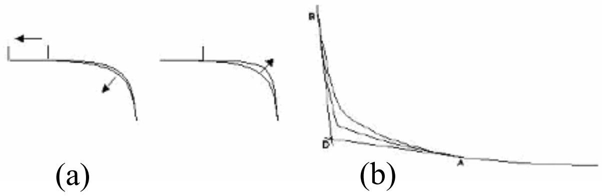


Fig. 10. Alternatives for creating more *lead in* (a) and the proposed *lead i*n measure (b).

Then, more *lead in* means a longer *lead in* with a start deeper inside the curve (see Fig.10(a)).

The measure we propose is given by the area between the tangents at the end points of the *lead-in*, i.e. the points **A** and **B** in Fig. 10(b), and the connecting *lead-in* curves.

2.11 Crown

Crown sounds as if it were only related to a specific action on a shape and not a property itself; in fact it is mainly used in the context of *"putting on more crown".* It means something like *lifting* or *raising* a certain part of the curve or surface, without changing the end points.

In principle, one can raise every kind of curve, but "*putting on crown*" can be better applied to already *convex* curves. If more *crown* is added to an *s-shaped* curve, it results in eliminating the inflection point and creating a *convex* part. *Crown* is always added in a given direction. Crowning must not increase the number of points on the curve at which the curvature has a local maximum or a local minimum. *Crown* can be measured simply by the maximum elevation of a curve with respect to a chosen base line corresponding to the connection between two important (user-chosen) points (see Fig. 11).

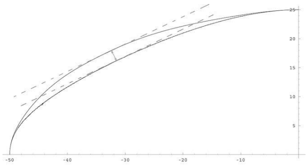


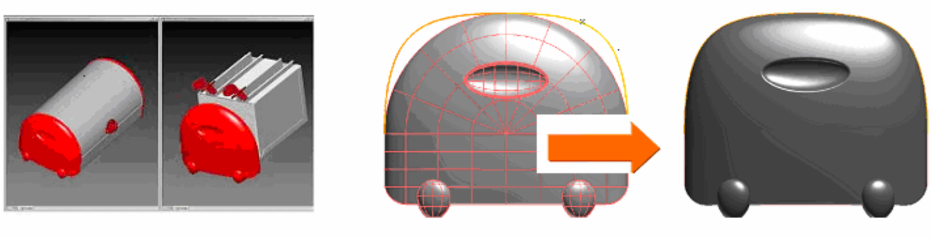
Fig.11. An example of crowing (upper curve) a part of a convex curve (lower curve)

Being useful only for modification, *crown* is not suited to be considered for evaluation purposes.

3. THE APPLICATION VALIDATION

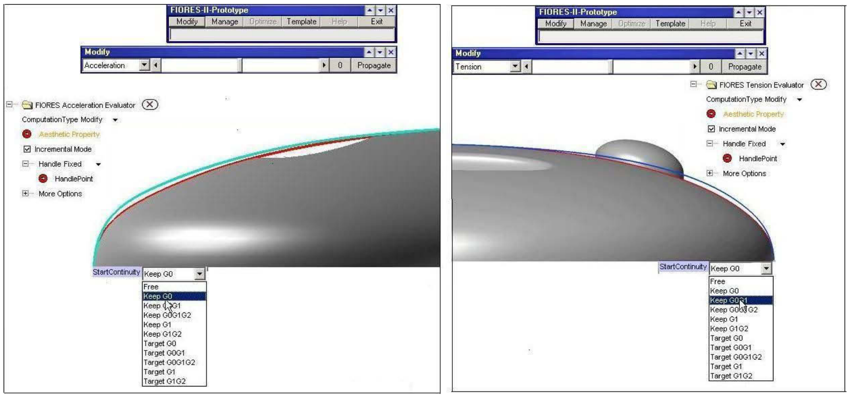
As already mentioned, the properties described in the previous section have been identified and analysed within the FIORES-II project. The main objective of the project is the definition of computer-aided tools able to help designers in obtaining faster the desired shape and in maintaining the given aesthetic character also during possible successive modifications due to the upcoming engineering constraints. This ambitious goal required from one hand the implementation of CAD operators acting directly on the mentioned styling properties; on the other hand it asked for capabilities for aesthetic character comparison in order to be able to decide whether a given character is maintained or not.

Being interested in the similarity of objects from the aesthetic point of view, the above properties seem to represent a meaningful means for shape comparison purposes. By analysing their evaluated measures, it is possible to have information on the combination of the associated geometric properties and hence, to somehow evaluate the shape appearance. Analogously, by specifying their changes, it is possible to control the shape. The developed software prototype is composed by several components operating through a common user interface, which can be connected via the CAxOPEN Product Data Channel[1] to other CAD systems. The current implementation of the operators is based on thinkdesign[2], the optimisation capabilities are provided by BossQuattro[3], while for the character management CBR-Works[4] is adopted.



(a) The breadbox and the toaster

(b) The convex operator is applied on the half of the to p curve and the result is mirrored and then propagated to the whole surface.



(c) *Acceleration* is increased to one section

(d) *Tension* is decreased to the half of the other section

Fig. 12. An application example

3.1 Styling properties as CAS modelling tools

Within the project, a subset of the previously described properties has been selected for the prototype development. The choice has been done according to the user preferences, which indicated the following as the most useful

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[1] PDC, www.caxopen.de

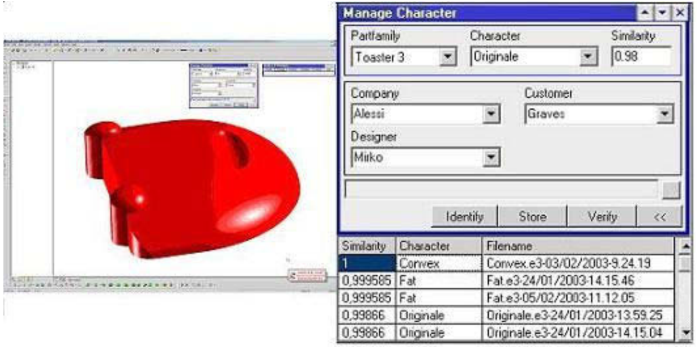
[2] thinkdesign is copyright of think3, www.think3.com

[3] BossQuattro is copyright of Samtech www.samcef.com

[4] CBR-Works© is developed by the AI-Knowledge Based Systems Group of the University of Kaiserslautern wwwagr.informatik.uni-kl.de

for their daily work:- Acceleration - Convex/Concave - Soft/Sharp
- Crown - Lead in - Tension

In order to provide the capability of satisfying engineering constraints while simultaneously maintaining the aesthetic ones, further improvements to the given measures have been done to obtain continuous and differentiable measure functions to be used in the adopted optimization. In Fig. 12 a practical example illustrates the use of the implemented operators applied to a real case developed at Alessi: to design from a given breadbox a new toaster that has to belong to the same product family (Fig 12(a)). [www.alessi.it]. The new product is obtained basically by changing the dimension of the starting object (front part) and then acting to the appropriate styling properties (Fig. 12 (b), (c), (d)). Using the modifiers, it has been demonstrated that the design objective is reached in a much more direct way than using the traditional functionality of most computer-aided design tools and the working time gained is proportional to the model complexity; in particular for this specific example, 4 minutes were necessary for the shown operations, while by using traditional tools the same results have requested 3 hours. This safe of time is also due to the capabilities provided by the hosting system for propagating the modification of the curves' properties to the selected surface regions. It should also be noted that, as it happens for the other modelling operations, the same shape results could be reached by applying different modifiers with opportune parameter values on different parts of the important curves.



Partfamily: Toaster 3
Character: Originale
Similarity: 0.98
Company: Alessi
Customer: Graves
Designer: Mirko

Similarity	Character	Filename
1	Convex	Convex.e3-03/02/2003-9.24.19
0,999585	Fat	Fat.e3-24/01/2003-14.15.46
0,999585	Fat	Fat.e3-05/02/2003-11.12.05
0,99866	Originale	Originale.e3-24/01/2003-13.59.25
0,99866	Originale	Originale.e3-24/01/2003-14.15.04

Fig. 13. The Manage Character window.

3.2 Styling properties for similarity assessment

We can use the measurement functions of the styling properties also for comparing the similarity of curves and surfaces.

The measures given were not designed to provide unique descriptive values for the particular properties; if a curve has a *straightness* value of 0.8, the absolute number does not mean anything, not even that it is twice as *straight* as a curve with *straightness* 0.4. The only conclusion we can draw from those values is that the first curve is *straighter* than the second. For the use in optimisation algorithms this is sufficient, because knowing whether to be closer or not to a target, means knowing whether a modification step was useful or not, while for general shape retrieval this could be a limitation. Nevertheless, even if completely different curves can present the same value for a specific styling property, they possess different values for the other styling properties. Based on this assumption, within the project, a similarity measure obtained by a weighted combination of the given styling property measures has been applied to the characteristic curves of the object, in order to evaluate whether a variation of a stored object still presents the attributed character. Due to the contextual validity of the aesthetic character perception, i.e. within a specific cultural environment, it seems almost impossible to associate a given character to specific shape characteristics in an universally acceptable way.

To overcome such problem, it has been decided to take advantage of the learning capabilities of CBR (Case-based Reasoning) tools for storing and managing the aesthetic character of products [18]. It allows storing classes of products having a specific character and to evaluate whether a variation of a stored object belongs to stored classes. Currently the prototype leaves it to the designers to specify the characteristic curves for a shape and to choose the portions on which the numerical value of each styling property will be calculated, whilst weights are learned by the provided examples and from user interaction. Considering the context-dependency of the character classification, additional non-geometric information needs to be taken into account to achieve a meaningful character specification and evaluation. In Fig. 13 it is illustrated the *Manage Character* window of the CBR-based developed prototype, which allows the user to verify if an object, owns a specified character.

4. DISCUSSION AND CONCLUSIONS

In this paper, an insight on the identification of modelling functionalities for design intent management in the context of aesthetic design has been presented. The concept of styling features and properties has been described and examples from the developed software tools have been provided. We have seen that the presented styling properties can be formally described and measured and that the proposed measures seem suitable to be used in interactive working procedures, with significant results.

Taking in account human perception, analysing the psychological aspects of similarity, and conducting own experiments concerning the judgement of curve similarity, we concluded that any attempt at finding the one and only similarity measure for arbitrary curves must, nevertheless, be regarded as wishing the impossible. It always depends on the application environment, which features are the important ones and what makes them look similar. In styling environments we must face the additional difficulty of emotional judgments that makes it likely that the similarity judgements can change from user to user and from object to object.

The similarity assessment based on local styling properties gives good results when applied to very similar objects presenting small shape variations and same number of characteristic lines. Therefore, it seems acceptable for the evaluation of the impact of small changes, e.g. due to new constraints. But is too limited for a general cataloguing and retrieval. We can enhance the set of measurement functions by using properties that are more generic and more global, i.e. geometric properties (mainly length, ratios, and curvature), having in mind that they may sometimes be too fuzzy to distinguish between globally similar parts, which show important local differences. In addition, it is worthwhile mentioning one essential difficulty when measuring styling curves: where does the curve start and where does it end? We do not yet treat the problem of how to reasonably select the start and end points of a styling feature.

5. ACKNOWLEDGEMENTS

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