CONTINUITY IN SPATIAL SURFACES FOR INDUSTRIAL DESIGN

Patricia Muñoz and Juan López Coronel

Faculty of Architecture, Design and Urban studies, University of Buenos Aires

Pabellón 3. Ciudad Universitaria

Buenos Aires, Argentina

patricia@plm.com.ar; info@jlopezcoronel.com.ar

Abstract:

The purpose of this enquiry was to verify the way in which CAD systems and their tools for visual surfaces analysis interact with morphological knowledge in the determination of continuity in products of industrial design. We acknowledge that geometrical knowledge is necessary but not enough for working with this attribute of form in everyday objects, where cultural factors are involved.

Geometry establishes a progressive range of continuity of surfaces that involves the concepts of position, tangency and curvature. In product design we find different degrees of continuity that not necessarily follow this idea of increment. What is understood as discontinuous in products in most cases is geometrically continuous.

The control of smoothness in the shape of objects, is influenced by the way in which the form was created and by the different communicational, functional and technological elements that identify a product of industrial design. Subtlety in the suggestion of form, by means of the regulation its continuity, is what turns it suggestive through design.

We consider that the development of the geometry of digital drawing systems in three dimensions should be an integrating process, where CAD developers and designers work closer in order to potentiate both activities.

Spatial surfaces [1] are a relevant field of work for the development of industrial design products. They are the only shapes that allow the continuous transformation between zones determined by opposite concepts, such as convex and concave, straight and curve, uniform and progressive.

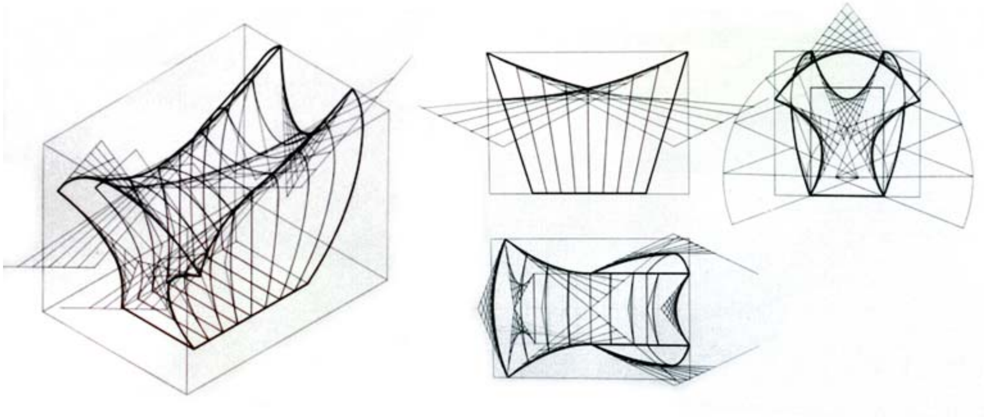

Figure 1. Surface that goes through a continuous transformation from convex to concave zones. Created by a student, Cardozo.

Various products, in particular those manufactured in plastics, are not conformed by a unique shape but are composed by a complex union of several simple surfaces. In product design, some areas of an object are differentiated that correspond not only to the diverse functional categories involved [2] but to visual, technological and operative issues as well.

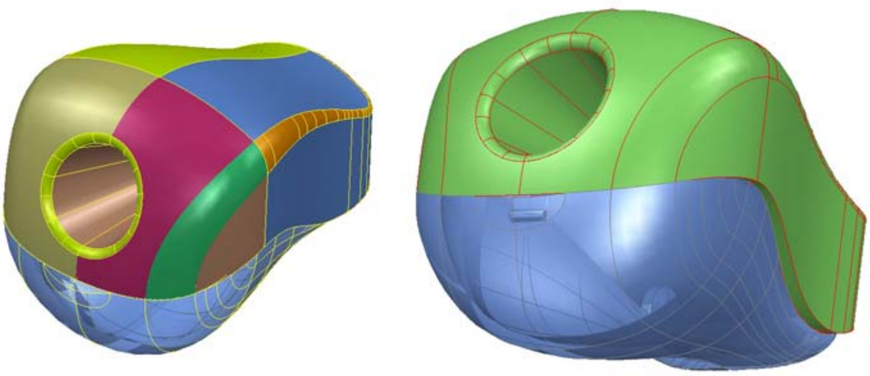

Figure 2. Drawings of the linked surfaces of a pencil sharpener.

Different degrees of discontinuity are established following not only geometric but also perceptual aspects, related to knowledge and social practices. We refer to perception in the sense that Gubern (1996:16) characterizes it when he says: “it is not a sensorial automation, but a complex cognitive elaboration of the sensitive data received”.

Starting from the different degrees of geometric continuity we included the development on morphology of spatial surfaces in the area of industrial design [3]. We worked integrating hand-made sketches, digital drawings and the tools for visual analysis these new media offer.

The purpose of this enquiry was to verify the way in which CAD systems and their tools for visual surface analysis interact with morphological knowledge in the determination of continuity in products of industrial design. We acknowledge that geometrical knowledge is necessary but not enough for working with this attribute of form in everyday objects, where cultural factors are involved.

Geometric continuity

Geometry establishes a progressive range of continuity that involves the concepts of position, tangency and curvature. CAD systems use this concept to provide tools for visual analysis that allow the designer to transform his design, based on the information supplied. For instance, the Zebra stripe analysis simulates that the model is built in a chromed material and is placed inside a cylinder with regular stripes in it. The reflection on the shape enables the detection of different types of continuity. This was a particular development based on a system that was used in automotive industry. Vehicles were placed in showrooms where the ceiling was lined with fluorescent lights strips. Their reflection on the model was studied in order to evaluate its shape.

Figure 3. Zebra analysis of two planes in contact (G0), of two quarters of a cylindric surface joined with an inflection line (G1. They share the tangent plane but curvature turns from negative to positive) and of two quarters of cylindric surface joined with tangent and curvature continuity (G2).

These tools allow designers to detect progressive levels of geometric continuity:
G0: Continuity of grade zero is also known as positional continuity. Is that in which the shapes are physically continuous but present edges or angles in the join.
G1: Continuity of grade one, of tangents, is that which has positional continuity and, in addition, the tangents in the union coincide. Curves appear as travelling in the same direction at the join.
G2: Continuity of grade two, of curvature, is the same as tangent continuity and in addition the curvature matches at the join. It is smoother than G1. Surfaces seem to have the same "speed" at the join. [4] The surface and its reflections are continuous. This is important in product design because in glossy surfaces unnoticed and undesired discontinuities are clearly evidenced.

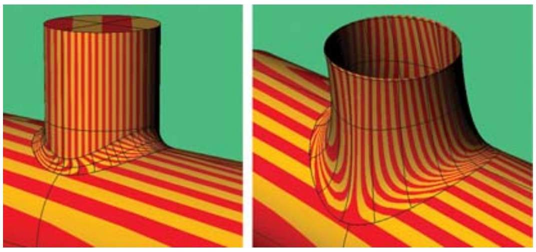

Figure 4. Continuity G1 in fillet surfaces and G2 in blend surfaces.

Even though the more frequently used CAD softwares do not analyze them, some programs can detect continuity of grade three and four (G3 and G4). In G3 cases there is positional, tangent and curvature continuity – as in G2- plus "the rate of change" of curvature between surfaces. Grade 4 continuity goes even further, sharing the attributes of G3 but adding "the rate of change of the rate of change" of curvature. These are surfaces frequently used in automotive industry, and can only be obtained with blend curves, that are a particular case of NURBS [5], with more construction information in them.

Morphological continuity

In product design we find different degrees of continuity that not necessarily follow this idea of increment. What is understood as discontinuous in products in most cases is geometrically continuous. In order to make this clear we must first explain the different ways in which complex surfaces are dealt with in the projecting practice of design. We identify four different processes.

1. *As intersection of forms*
2. *As union of simple surfaces*
3. *As complex movements of a generative line*
4. *As transformations of control points in meshes.*

1. As intersection of forms

Complex surfaces are obtained as the result of the intersection of two previous forms. It can be through addition or substraction. In this case continuity is built with fillet surfaces – of uniform or variable radius- or blend surfaces.

There is a tension between the recognition of the original shapes and the understanding of the result as one form that at the same time includes and hides them. So this seductive game appears where forms are subtly and simultaneously hidden and unveiled.

The geometric continuity that can be obtained by these kinds of linking surfaces is G1 for fillets, and G2 for blends. However, from a perceptual point of view, fillets can be made more or less continuous according to other parameters. These are related to the degree of intervention in the original shape that interferes in the recognition of its identity. The variation of the linking surface allows an efficient integration by breaking the identity of the parts. Paradoxically we have detected that the greater the variation of the surface corresponds to a lesser segmentation of forms.

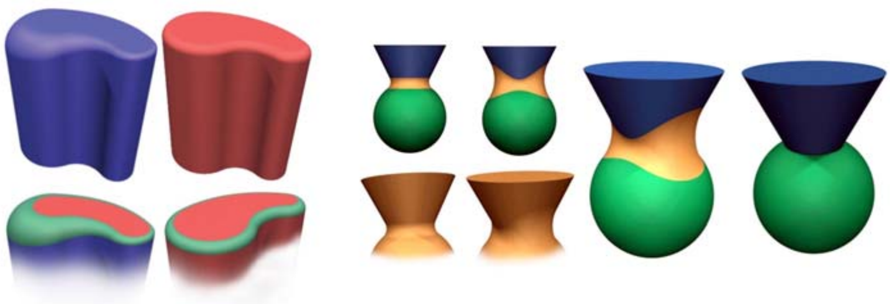

Figure 5. Fillets between a cylindric surface and its cap and between a cone and a sphere. The union is smoothed if the symmetry of both shapes is diminished by the linking surface.

From a morphological point of view it is conceptually possible to use fillets with huge radius, but many CAD systems limit this possibility. In order to get the desired effect, designers end building their shape with other tools using the concept of fillets.

The intentional selection in the areas to be smoothed eliminates the amoebas that have invaded our everyday objects creating a tension between continuous and discontinuous, smoothness and edges, that makes these shapes more attractive. This can be clearly noticed in Figure 6.

Figure 6. Student's design starting from the subtraction of four spheres from a cube. Selective fillets break the original symmetry and link some adjacent faces. Even though continuity is increased some edges are maintained that emphasizes the tension between smoothness and discontinuity.

2. As union of simple surfaces

Traditional geometry considers a surface as the result of the movement of a line (generative line). Classic surfaces can be so explained by means of simple movements such as rotation, translation and some particular combinations. The movements of rotation and translation combined are used to create forms, even though they are usually considered only in its most simple case: where rotation takes place in a vertical axis that is coincident to the directive line (or path) of the translation. If the generative line changes its movement the result is understood as two linked surfaces. Many CAD tools have followed this organization scheme.

These complex surfaces are organized with relation to structuring lines that are usually compared to the sewing lines of a shirt, or the structuring lines of a sunshade. These lines are the shared boundaries of the different generative systems used. Continuity is established not only by the coincidence of the generative line in those limits but by the continuity of the curvature of adjacent surfaces. From a projectual point of view this is manipulated by the introduction of continuous structuring lines that cross the different surfaces, controlling the variation. These surfaces can be observed in the pencil sharpener in Figure 2.

In this case continuity is something desirable in order to avoid undesired lines or visual disturbances of the smoothness of the surface. There is no intention of allowing the recognition of the component surfaces, as it was in the previous case.

3. *As complex movements of a generative line*

In this instance, form is the result of a complex movement of the generative line, that not necessarily is identical – as in the traditional generative systems- but can be selectively transformed. For example the movements of double rotation, translation with rotation in different axis, or cross-sections on translations that control the variation of generative lines and its location. Some CAD systems tools are based in simple generative systems but produce complex shapes by allowing the transformation of every variable involved. For example translation with rotation, controlled by the tangents to the curve that is the path. Other tools admit the combination of movements, getting continuity through a single –even if it is complex- indication.

In this case continuity is greater, and different software give alternatives to regulate continuity so that marks or bumps are avoided. It is difficult to have a conceptual preview of the most complex movements so it is frequent to go through processes of trial, error and adjustment to get to the final shape. Strangles or wrinkles may appear because of difficulties in complex calculations. These can be avoided working on the parameters of the shape.

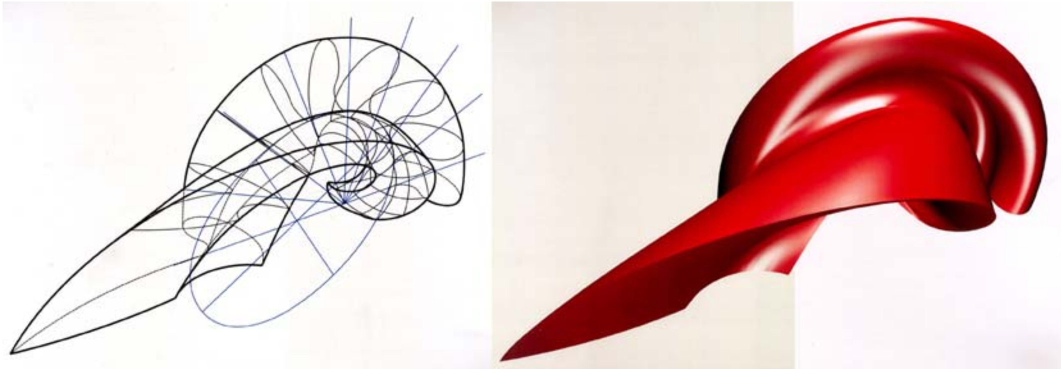

Figure 7. Student's design of a surface produced by double rotation with transformation of the generative lines.

4. As transformations of control points in meshes.

The movement of control points transform simple meshes –that can either be in 2 or 3D- into complex shapes. This type of work on the changes through poins on meshes is quite useful when we look for "expressions" over the control of the behaviour of form. It offers an immense freedom of configurations but a greater difficulty in the control of its geometry as well. These transformations can produce a new continuous shape but can also be used to define perceptually discontinuous areas.

Figure 8. Different animal packagings where expressions are obtained by minimal movements of points in space that transform the meshes.

Intentional continuity

There is a desirable continuity in the form of products that is relevant not only if we consider visual aspects but because of technological issues as well. Less "speed" in the flow of plastic on a mold will require the use of heaters in matrices so that the plastic does not block its path. This increases costs and also implies an accumulation of material in some parts that modifies the resistence of the surface. However this last issue is not necessarily a negative aspect because it can be used deliberately to increase the strength of an area.

Continuity of sections has also its influence in the behaviour of the object and can produce deformations or shrinkages if they are not smooth in its changes. It is a knowledge that can cause undesired and costly surprises if it is eluded but can also be used intentionally in design.

However, the need to synthesize in the shape of a product the different communicational, functional and technological elements frequently requires the inclusion of different degrees of controlled discontinuity. For instance, a discontinuous area could be developed to determine a handling zone or a lid.

While working with discontinuity in complex surfaces, some of the structuring or generative lines are selected in order to produce discontinuities according to its geometry. So, they are not seen as sewn patches but as a coherent part of the whole.

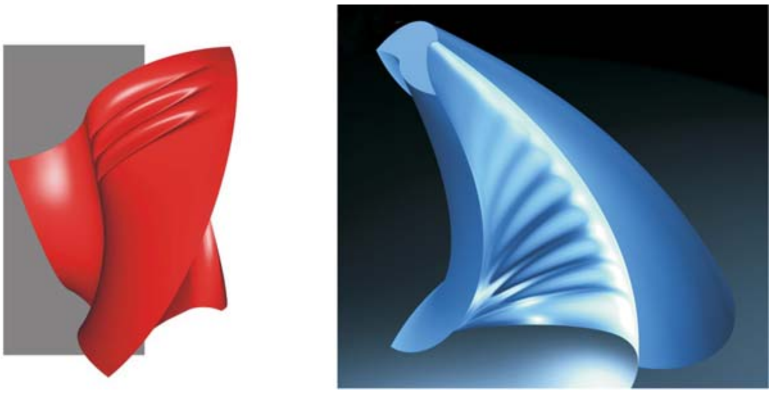

Figure 9. Examples of discontinuous areas in complex surfaces defined by generative lines, from students Delatorre and Lanza.

While working on a simple surface the discontinuities introduced in the basic shape can be more complex. The identification of main lines that organize this morphological discontinuity may be continuous geometrically such as can be seen of the bottle in Figure 9. The designer can work with different degrees of geometric continuity while sustaining the perceptual discontinuity.

Figure 10. Perceptual discontinuities in a geometrically continuous bottle, as can be seen by the zebra analysis. Continuity of G2.

The limits that divide discontinuous from continuous are small and vague. They cannot be determined accurately because the scale of variation in relation to the whole shape plays a significant role in this interpretation as well. These boundaries determine the identification of a discontinuous area or the integration of the transformation in the form.

The regulation of continuity in the shape of objects, allows us to establish a tension between what is obvious and what is unknown, between what is evident and what is hidden. The interior or the geometry of a shape is partially unveiled through the perception of the covering outside. So, subtlety in the suggestion of form is what turns it suggestive through design.

We consider that the development of the geometry of digital drawing systems in three dimensions should be an integrating process. Computer science developers should continue developing new CAD tools for the generation of shapes but designers should work together with them because there is a need of new instruments for our morphogenerative activities that are not yet available, or sometimes are too far from our projectual practice. The distance between software developers of CAD resources and designers should be bridged in order to potentiate both activities. We have shown that continuity is one of the issues but there is much more to be done.

Notes:

[1] Typology of the "System of Figures" developed by Doberti (1971)
[2] Let us remember that functional categories are the different zones of an object that can be recognized not only in their operational possibilities but also in the communication of the actions they promote.
[3] Research projects at the Morphology Lab, SICyT, FADU, and developments in our three annual courses on Morphology in Industrial Design at the University of Buenos Aires, Argentina. More information on student's work on surfaces at http://www.plm.com.ar/academico.
[4] It is important to make clear the concept of "speed of a curve", based on the idea of curvature. In Background information on curve geometry for Alias users, it is defined as "the rate of change of the direction, also called curvature."
(See http://www.lsi.upc.es/dept/investigacion/sectig/web-ig/alias/Modeling/Background.fm.html#132126)
The speed of a curve is an interesting and frequently used concept in our courses on morphology. As it is explained later it is linked to manufacturing matters as well.
[5] NURBS stands for Nonuniform rational B-splines and are used by most CAD systems.

References:

DOBERTI, Roberto et al. (1971)– Sistema de Figuras, Revista Summa Nº 38 -Buenos Aires
GUBERN, Roman (1996) Del bisonte a la realidad virtual. Ed. Anagrama, Barcelona