COMPUTER AIDED DESIGN TOOLS AS APPLIED TO AESTHETIC DESIGNS

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ABSTRACT

Computers have now found applications in almost every field of engineering now, the same applies to mechanical engineering also with computers been used in the field of design and analysis of components. In this paper we have attempted to explain the utility of computers in the field of aesthetic design of components or system as a whole. Aesthetics are the components of design, which affect the visual importance of the component hence we have tried to explain the application of curves with different continuities to elaborate and make the design procedure better and more pleasing. The various tasks involved in the aesthetic design procedure have also been discussed and their inherent advantages and disadvantages have also been discussed.

KEYWORD

Mechanical Engineering	Computer
Design	CAD
Quality	Loop
Virtual	Surface

Preface

In this article, we are concerned with computer-aided design tasks in which the final evaluation is mostly based on aesthetic criteria. While most engineers accept the fact that one needs to use computers to design jet engines, computer chips, or large institutional buildings, it is less clear whether computers are also useful in the design of artifacts that are judged mostly by their looks. In a traditional CAD setting, the computer primarily serves as a precise drafting and visualization tool, permitting the designer to view the emerging geometry from different angles and in different projections. A digital representation also makes it possible to carry out some analytical tasks such as determining volume or surface area of a part.

Creating maximally satisfactory forms for mathematical models or for geometric sculptures poses quite different requirements and constraints for any CAD tool than developing an optimized airplane wing or designing the most powerful computer chip. Real-time interactivity becomes a crucial factor, when a designer's eye is the key evaluation instrument in the design loop.

This article overview starts by looking at some generic tasks in curve and surface design, in particular, ongoing efforts for defining a beauty functional for procedurally optimizing shapes that are only partially constrained by the designer. It then discusses some research aimed at finding efficient implementations and approximations of such optimization functionals, so that they can be used at interactive design speeds. Next, we look at a parameterized design paradigm that allows an artist to rapidly explore and compare many alternative versions of a geometrical shape. Finally, we make the point that a CAD tool that is well matched to the task at hand is much more than just a 'drafting assistant' and can indeed become an amplifier for one's creative spark.

Smooth surfaces play an important role in engineering and are a main application for many industrial CAD tools. Some surfaces are defined almost entirely by their functions; examples are ship hulls and airplane wings. Other surfaces combine a mixture of functional and aesthetic concerns, e.g. Car bodies, coffee cups, flower vases, etc. Finally, for some cases, aesthetics dominates the designer's concern, for instance in abstract geometric sculpture.

For either situation, it can be argued that an ideal surface design system should allow a designer to specify all the boundary conditions and constraints and then provide the 'best' surface under these circumstances. Best in the context of this article would mean an optimization with respect to some intrinsic surface quality related to its aesthetic appeal. To be usable in a CAD tool, that quality has to be expressible in a functional or procedural form. Commonly, the characteristics associated with 'beautiful' or 'fair' surfaces imply smoothness at least tangent-plane (G^1-) continuity, but often also curvature (G^2-) continuity. If the surface is covered with some textural pattern, then we have to demand more than just geometric continuity and also require smoothness of the parameterization, i.e. C^1- or C2-continuity, respectively. Additional characteristics often cited in the definition of aesthetic shapes are symmetry and simplicity. The first implies that symmetrical constraints should result in symmetrical solutions; and the second implies avoidance of unnecessary undulations or ripples.

All these properties are exhibited by minimal surfaces, i.e. By the shapes assumed by thin soap membranes spanning some given boundary (as long as the air pressure on both sides is the same). Experimentally, such shapes can be generated by dipping a warped wire loop into a soap solution. The lateral molecular membrane-forces will try to minimize overall surface area and thereby implicitly create a minimal saddle surface in which the mean curvature at every point of the surface assumes the value zero. Now, a decade later, what are the prospects for evaluating such functionals at the desired, almost instantaneous and truly interactive rate?

- First, of course, computer power has increased by one to two orders of magnitude over the last decade, thus bringing us closer to our goal of full interactivity, even without any further innovations.

- Second, and most importantly, subdivision surfaces have become mature and popular. They allow us to obtain surfaces with a reasonable degree of built-in continuity by their inherent construction, thus avoiding the very costly inner optimization loops that were used originally to guarantee smoothness at the seams.

- Third, the inherently hierarchical organization of sub- division surfaces gives us the possibility to optimize the gross shape of the surface at a relatively coarse level, where only a small number of control points have to be adjusted. Then as we gradually refine the surface by increasing the level of subdivision, the number of degrees of freedom grows at a quadratic rate; but since the surface is already relatively close to the desired shape, the optimization procedure need not run for many iteration to achieve convergence

- Fourth, at the research frontier, experiments are now under way to find means to avoid the expensive numerical integration steps in the inner loop of the optimization. The aim is to find a discretized approximation of the salient surface characteristics, to obtain directly an estimate of the behavior of the cost functional that is good enough to guide the gradient descent optimization in the right direction

As our basic framework, we use subdivision surfaces to represent the shapes to be optimized. Using finite differences based on incremental movements of the control vertices, a gradient vector for the chosen cost/energy functional is obtained and then used to evolve the surface iteratively towards a local cost minimum. After obtaining the minimum energy surface for a given mesh resolution, the mesh is subdivided to produce new vertices and therefore new parameters for optimization. In this general approach, we can vary the methods for calculating the actual optimization moves, trading off accuracy for speed.

As a baseline for comparing the various methods, we use exact evaluation of the subdivision surface sampling the limit surface to obtain its geometric properties. Using differential geometry and numerical integration by Gauss-Legendre quadrature, we can compute it with high accuracy a cost functional such as the bending energy. Using this energy computation in the above framework, we can obtain robust results that agree with the theoretically known energy minima for some highly symmetrical smooth surfaces, such as spheres, torus, or the known energy minimizes of higher genus. Since numerical integration and gradient calculations are computationally expensive, this method may take a few hours for surfaces however, it serves as an excellent benchmark for evaluating more approximate methods.

A first simplification calculates an approximate cost functional directly from the discrete mesh of control points of the subdivision surface, as is done, for instance, in. We are exploring vertex-based as well as edge-based functional that express the surface energy as a summation over the local energy at all the vertices or edges. These local energies are calculated with a discredited approximation, using polynomial expressions of vertex coordinates and/or dihedral angles along the edges. These simpler functional are adequate to guide the gradient descent process in the same direction as a more exact functional evaluation would, but do so at significantly reduced cost and thus with higher speed

Interactive CAD applications

With this speedup resulting from the use of discrete functional and/or direct vertex-move calculations, we can envision a CAD system in the not-too-distant future, where the designer specifies boundary conditions and constraints for a surface panel and then picks a suitable cost functional for a quick optimization of the surface. The designer may compare and contrast the results of using two or three different aesthetic functional and choose the one that is most appropriate for the given application domain. The designer further can adjust some of the original constraints or add new ones to force the surface to meet functional as well as aesthetic expectations. The role of the chosen functional is to take care of the details of the surface shape, e.g. to avoid geometric discontinuities or unneeded wrinkles and slope changes

A second key CAD problem is the embedding of beautiful or fair curves onto the kind of optimized surface discussed above. For instance, one may need to draw a fair connecting line between two points on a smooth surface.

The most direct such connection is a geodesic line, which exhibits no gratuitous lateral curvature. While it is easy to trace a directional geodesic ray on a smooth surface or on a finely tessellated polyhedral approximation thereof, it is a well-known hard problem to connect two points with the shortest geodesic path on a surface that exhibits many areas of positive and negative mean curvature.

Sometimes the geodesic line segment is too restrictive for design purposes; it offers no degrees of freedom or adjustable parameters to the designer. This limitation is particularly detrimental when multiple lines must radiate from the same point. In this situation, a designer would like to have some control over the initial tangent directions of these lines, perhaps to distribute them at equal angles around the point from which they emerge.

The question arises, whether a commercial CAD tool, such as AutoCAD, SolidWorks, or Pro Engineer, would have been adequate to model Collins' sculptures. Indeed, with enough care, spline surface patches and sweeps could be assembled into a geometrical shape that would match one of Collins' creations. But this approach would be lacking the built-in implicit understanding of the constructive logic behind these pieces, which we wanted to generalize and enhance in order to produce many more sculptures of the same basic type. For that we need stronger and more convenient procedural capabilities than those that commercial CAD tools had to offer.

Capturing a sculpture as a program, forces us to understand its generating paradigm. In return, it offers precise geometry exploiting all inherent symmetries, as well as parametric adjustments of many aspects of the final shape. The latter turns out to be the crux of a powerful sculpture generator. If we build too few adjustable parameters into my program, then its impressibility is too limited to create many interesting sculptures. If there are too many parameters, then it becomes tedious to adjust them all to produce good-looking geometrical forms. Figuring out successful dependencies between the many different parameters in these sculptures and binding them to only a few adjustable sliders is the intriguing and creative challenge.

In practice it turned out that almost every sculpture family that we tackled, required a new program to be written. These programs become virtual constructivist 'sculpt- sculpting tools'. Once a new program starts to generate an envisioned group of geometrical shapes, it often will take on a life of its own. In a playful interaction with various sliders that control the different shape parameters, and by occasional program extensions, new shapes are discovered that were not among the originally envisioned geometries. In this process the original paradigm may be extended or even redefined, and the computer thus becomes an active partner in the creative process of discovering and inventing novel aesthetic shapes

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