Chapter 33

Models for Design: From Geometries to Generative Algorithms

Michele Calvano
Sapienza - Università di Roma, Italy

ABSTRACT

In this chapter, geometrical algorithms are illustrated to resolve problems present in the creative process when designing a product. If it is explicit and automated, the algorithm can serve as a useful tool during the product design process. The objective is to simplify the step between the digital and physical models and vice versa, which is typically a necessary alternation when creating products. Two important operational areas are illustrated. One is related to digitally representing the product. The other deals with resolving the continuous comparison between the digital and real models. The need to compare the two models is due to the designer’s need to construct full-scale prototypes. It is important to maintain these initial physical prefigurations of the idea because they may be modified and can inform the continuously evolving digital model.

INTRODUCTION

Problems

Modelling a product for its digital representation is characterized by several difficulties, which this research presents by proposing some determined scenarios. In the first place, synthesizing complex models in efficient ways that guarantee modifiability leads to a deep knowledge of the methods of digital representation usually used by designers. Continuous representation makes use of non-uniform rational B-spline (NURBS) surfaces and discrete representation uses mesh surfaces. Those who approach such problems should understand the differences between the constructed model and the digital model. The first, in fact, presents a shape continuity that depends on the means of production and is sometimes difficult to reproduce digitally. A printed object, for example, presents itself with a shell lacking a continuous solution due to the surfaces that determine its form. This condition is difficult to recreate with a digital model if we trust a continuous representation, since NURBS surfaces are limited to a clear topology and clear production methods.

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In addition to analyzing the shell, the parts composing the forms in the structural geometries can be synthesized. This includes axes and planes that support the revolution of simple curves and parts that are symmetrical, or in some way balanced. These are all important elements connecting the digital model to the prototype.

For topological questions, and by necessity constructive questions, it is illustrated how to recognize the patches constituting the form, creating continuity between the connected parts in order to simulate the outline of the product with a single surface.

Surfaces, axes of revolution, and planes of symmetry are qualities that can totally or partially define the form, and they also serve to connect the physical and digital models for reverse modelling. In this continuous step from real to digital, even the acquisition should be extremely concise.

**Context and Main Themes**

When describing the basic theorem of the architectural model in the first part of his text ‘Disegno come Modello’ (*Design as a Model*), Riccardo Migliari describes the relationship that exists between model $M$ and model $m$. In the formulation, $M$ represents the idea of a form and $m$ represents its possible representations.

The models $m$ are revealed through developments that go from free-hand sketches to technical and production designs. This expressive type also covers digital numerical and mathematical models and all derivative representations, such as static and dynamic renderings and physical models. The latter are characteristic of 3D printed models or the multi-material models generally used for architecture. All of these representations aim for $M$, thus building a design path that leaves traces in each representation. In fact, the representations meet and merge ‘without continuous solutions, in a spiral process that converges on model $M$, perfecting it without ever reaching it’ (Migliari, 2004).

**Ideas and Models**

In the text, Migliari contemplates a dynamic, evolving relationship, considering short steps from one representation to the next. The logic that emerges is what the designer ordinarily uses during the design process. This circularity works as an idea, but in reality has limits regarding the existing relationships between the mathematical and physical models (the prototype). These are slowdowns that impede the physical model from quickly forming part of the design process.

Because it is considered a design tool, the prototype should be immediately usable and understandable. The sketch, the technical design, and, increasingly, the digital representation already are so thanks to extremely communicative graphical interfaces.

The prototype is also required by the rapid succession of different models in order to clearly evaluate the form. This step is much quicker today: if the project is represented mathematically, appropriate algorithms tessellate the continuous model and transpose it numerically, representing it as a polyhedral surface (Migliari, 2010). The numerical model is the only model capable of being read by the prototyper, which represents the model physically. The time necessary to do so is determined by the layer-by-layer draft from the 3D printer or the speed of an automatic cutter. The different models $m$ are compared with the mental model $M$ thanks to the possibility of updating each and especially thanks to their direct relationship with the computer, which is today the true link between the production and creative processes. The more the model can be interfaced with the plotter, the quicker and more useful its support is for the
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