FOREWORD: CAD in the Arts and Creative Media

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I have been using computers to help artists since the mid 1990s. My first collaboration was with wood sculptor Brent Collins, living in Gower, MO. It was prompted in 1994 by a picture of a small wood sculpture called "Hyperbolic Hexagon" (Fig. 1a) [2]. The loop of six holes and saddles is reminiscent of the central portion of Scherk's "2nd Minimal Surface." This correspondence led to an interesting discussion and inspired us to explore what shapes might result, if this paradigm was extended to toroidal rings with a different number of holes, to higher order saddles, or to structures in which the hole-saddle chain was subjected to some longitudinal twist before it is closed into the toroidal loop.

Since the number of ideas that we came up with far exceeded what we could construct even as rough conceptual models, I developed a computer program, called "Sculpture Generator I," to captured this basic paradigm and to visually evaluate the many possibilities [4]. Gradually, I introduced more parameters to fine-tune also the thickness and extension of the flanges as well as the profile of the edges; this allowed us to optimize the aesthetic appeal of a possible finished sculpture. The program was used in 1996 to design the wood master for "Hyperbolic Hexagon II," presented by Brent Collins in Figure 1b. This was our first collaborative piece. Once we both had agreed on the detailed design, I captured this shape with a dozen full-size blueprints, representing cuts 7/8 inch apart through the whole structure. Collins cut these patterns from wood boards of corresponding thickness. After stacking and gluing them in the proper order, he then brought out the fine geometric details of the hyperbolic surfaces using his skills as a wood sculptor, honing the overall shape to perfection.

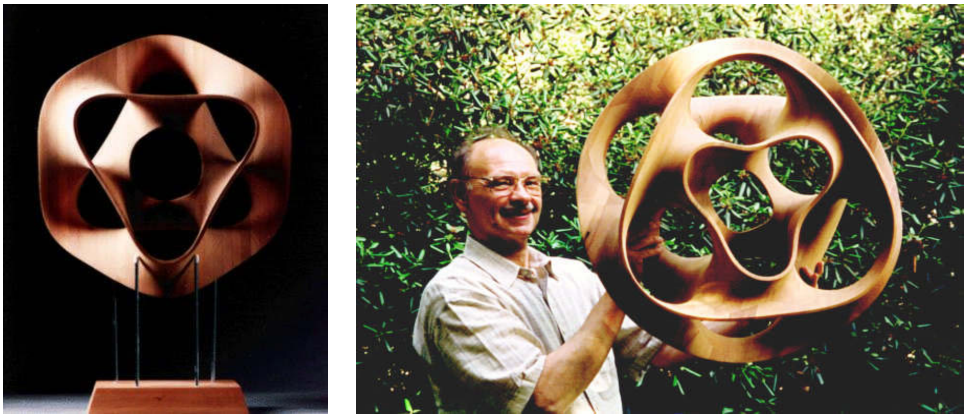

Fig. 1: Wood sculptures by Brent Collins: (a) the original "Hyperbolic Hexagon" (b) our first collaborative piece "Hyperbolic Hexagon II."

In 1995 the College of Engineering at U.C. Berkeley acquired two rapid-prototyping machines, a Fused Deposition Modeling Machine from Stratasys and a 3D-printer from Z-Corporation. That is when I really started to experiment with my *Sculpture Generator I*, producing dozens of virtual designs, which I then was able to fabricate as small prototypes, 3 to 4 inches in diameter within a day or two (Fig.2a,b).

Fig. 2: Creations from *Sculpture Generator I*: (a) "Three Cinquefoils" (b) "Family of 12 Trefoils."

Some of the more attractive shapes were subsequently fabricated at a scale of about 8 inches in diameter. I sent some of these plastic maquettes made on our Fused Deposition Modeling (FDM) machine to Steve Reinmuth in Eugene, OR, for bronze casting. Steve had figured out how these ABS-plastic shapes could be converted into bronze casts in a "lost-ABS" investment casting process, directly analogous to the traditional lost-wax process; at a high enough temperature the ABS plastic sublimates cleanly. Results of this conversion process are shown in Figure 3.

Gradually I expanded the capabilities of my generator to allow, for instance, to affinely stretch the Scherk-Collins toroids into totem-like sculptures (Fig. 3b) or to wind them more than once around a toroidal loop without causing self-intersections (Fig. 3c).

Fig. 3: Bronze casts: (a) "Cohesion" (b) "Totem 4" (c) "Doubly-wound Quad."

Many people have used *Sculpture Generator I* to create artistic artifacts such as ear rings or small pendants. However, this *saddle-ring* paradigm is rather limited. There are many other sculptures with quite different geometries. To capture their essence requires completely new programs. Over the last 10 years, several other sculpture modeling programs have been created by my students. Most of these have been based on Berkeley SLIDE [6], a more generic modeling and visualization environment, comprising powerful CAD modules such a generalized sweep generators, various subdivision surfaces, and powerful grouping and instantiation operators.

SLIDE was first used to emulate "Pax Mundi," another small wood sculpture by Brent Collins, which has a quite different underlying generating paradigm. In this case, the key concept is a ribbon undulating along the surface of a sphere in a symmetrical curve with 8 hairpin turns. I was fascinated by its exquisite elegance and also captured it in a computer program. This proved to be very useful several years later when Collins got a commission from H&R Block to scale up *Pax Mundi* into a 6-foot diameter bronze sculpture for the courtyard of their headquarters building in Kansas City. My SLIDE program was then readily able to adjust the dimensions to the required size and to slim the ribbon down to fit this large-scale metal sculpture and to keep it within its weight and budget limits. Figure 4a shows the finished sculpture "Pax Mundi 2," which is again a collaborative effort between Brent Collins, Steve Reinmuth and Carlo Séquin.

Fig. 4: A different paradigm: (a) "Pax Mundi II" (b) "Maloja" (c) "Hilbert Cube 512".

Over a couple of years, I again extended this generator paradigm. First I just enhanced the complexity of the undulation of the ribbon, so it started to look like a twisty road winding up a steep mountain. This resulted in a series of sculptures, collectively called "Viae Globi" – "Roads on a Sphere." Depicted in Figure 4b is "Maloja," named after a mountain pass in Switzerland. Later I also let the ribbon leave the surface of the underlying sphere, so that I could form actual knots, such as the "Chinese Button Knot" (Fig. 4c).

SLIDE also allowed me to create many other pieces of "artistic geometry" ranging from mathematical demonstration objects such as the genus-2 Costa surface in a cubic box (Fig. 5a) or the space-filling Hilbert Curve with 512 elements (Fig. 5b), to free-form artistic shapes such as the twins "Aurora Borealis" and "Aurora Australis" – which were inspired by the celestial displays one may observe near the Earth's poles.

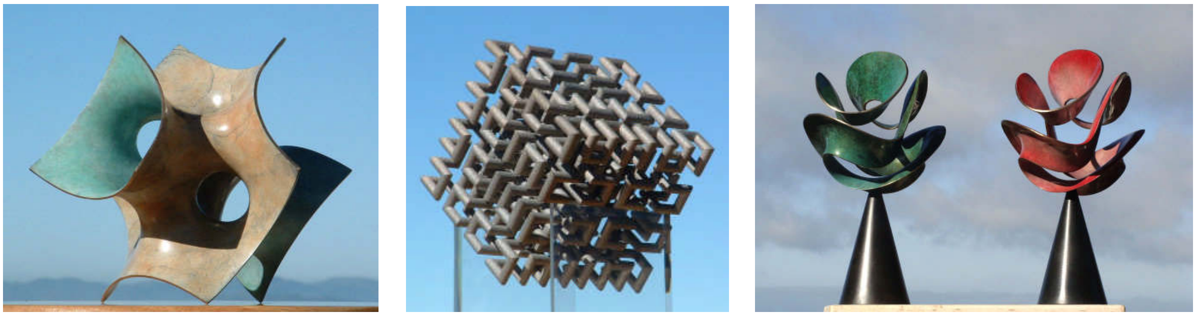

Fig. 5: Other creations using SLIDE: (a) "Costa in a Cube" (b) "Hilbert Cube" (c) "Two Auroras."

During this last decade, several artists have started to embrace also commercial CAD programs to design small sculptural forms or jewelry, which they then had fabricated by one of the layered manufacturing process offered through many emerging rapid-prototyping companies. Now there exist fabrication process that can build metal parts directly. Most noteworthy artist-users of such a process are Bathsheba Grossman [3] and Vladimir Bulatov [1].

At the CAD conference in Reno in 2009, Les Piegl asked me to be the guest editor for a special issue on "CAD in the Arts and Creative Media." It had been nine years since I had done a special issue for Computer-Aided Design [5], and at that time the use of CAD tools by artists was still rather limited. Thus I could not resist the temptation to find out who might be the new users of CAD tools for artistic purposes and what new applications might have emerged in the mean time.

The response to our call for papers has been quite diverse and has came from some surprising directions. Overall there is a clear emphasis on "applied art." The six papers in this special issue span applications of computer-aided tools for art-oriented tasks that range from the purely 2-dimensional domain of images to the 4-dimensional space-time continuum of movable kinetic sculptures. The selected papers will be presented in that order:

The first paper by Arroyo et al. describes an interactive, semi-automatic stippling system that mimics as faithfully as possible the artful stippling process done by the hands of experienced illustrators. It comprises a generator for irregular dot shapes that resemble the ink spots resulting from manual stippling techniques, as well as sophisticated techniques to place these dots in ways to avoid any annoying machine-generated patterns.

After this purely 2D application we enter the 2.5-dimensional domain of bas-reliefs. Kerber et al. apply highly effective techniques to compress a "deep" 3D scene into a bas-relief with very limited overall depth variation. These range-compression techniques were originally developed to handle high-dynamic range images on an output device with a much smaller dynamic intensity range. Using the latest graphics acceleration hardware, they are able to do the necessary computations in a small fraction of a second, so that it is even possible to make bas-relief movies based on dynamically changing 3D scenes.

With the paper by Gulati et al. we cast a glimpse on a semi-automatic generator for decorative bas-relief patterns that can be wrapped around the typical plastic bottles used sell potable water or soft drinks. A parameterized little figure generator is used to create ornamental tiling patterns, which are then suitably extruded and warped in space to create the moulds for such plastic bottles.

A more advanced shape generator by Wannarumon et al. employs fractal designs emerging from an iterated function system to design small jewelry pieces such as ear rings or pendants. The design interface employs user-stated preferences to retrieve some previous designs that embody those design goals as much as possible, and then rely on genetic algorithms to evolve promising designs under the user's guidance.

In the fifth paper R. E. Wendrich takes a more fundamental look at the design process for 3D objects in general. He reports on user studies that demonstrate that handling tangible, physical materials seem to enhance the early creative phases of the design process. He then proposes a new type of design work station that offers some of these same advantages in the context of a virtual computer environment.

Finally, Furuta at al. present an interactive CAD system for designing kinetic 3D sculptures such a mobiles and balance toys. An interactive drawing interface for shaping and connecting different parts is enhanced with a simple simulator that shows in what directions the various parts would move from the current starting condition. The user can then adjust the various suspension points to achieve the desired balance. The system also gives some indication of how stable the achieved balance may be.

Overall this is a broad and interesting range of applications. Most of them primarily use the computer to make it easier for users, who are neither well-trained artists nor sophisticated computer experts, to quickly generate some artistic artifacts. In all cases interactivity was an important component, and thus the design of a suitable user interface was a key concern. None of the described prototype systems have the breadth or robustness of commercially available CAD programs, but they all break new ground in some interesting direction.

Also, the field of practitioners has become much more international. In the 2001 issue [5], all papers were either from the USA or from Japan. This time the contributions come from Spain, Germany, India, Thailand, Japan, and the Netherlands.

The use of CAD tools in the arts and creative media is an accelerating trend. More powerful computers, more readily accessible and freely available software modules, and a broader basis of general computer education will entice ever more people with an urge to do creative things to enlist a computer as an assistant and as an amplifier for their creativity. I am sure that over the next decade, there will be much more activity in this domain, with ever more powerful generator programs and ever more user-friendly user interfaces.

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