The Digital Modeling of Frank Stella's Smoke Sculpture

Michael O'Rourke

From 1991 through 1992 I worked for the artist Frank Stella on a series of "smoke sculptures" that involved using the computer to model sculptural forms derived from smoke. The project began with Stella's interest in the forms of a smoke ring as it is blown and then slowly drifts and breaks up into a network of whorls, streams and eddies. I was asked to see if I could model these forms using three-dimensional computer modeling techniques.

figure 1

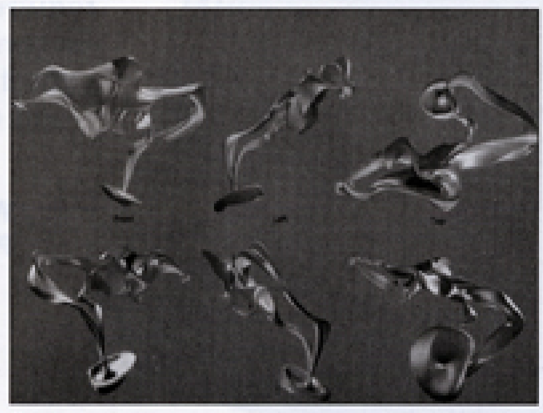

figure 2

Above: Frank Stella, *Zimming*, 1992. Stainless steel, bronze and aluminum, 16 x 13 x 12 in. The two forms emerging from the bottom are two of the smoke sculptures modeled on the computer.

Left: The smoke sculpture illustrated here, seen from six different points of view, is the same form seen at the bottom right of figure 1. This form was modeled entirely digitally.

After considerable experimentation, we did, in fact, develop a technique to produce forms that proved interesting and which Stella used extensively in his "French Mining Towns" series. An example of one of these pieces is shown in figure 1. The digital version of one of the smoke sculptures used in the piece is shown in figure 2.

The modeling process for each smoke form began with photographs of the smoke. Six simultaneous photographs, one taken through each side of a specially constructed box, were produced. One of these photos is shown in figure 3.

These photographs were scanned into the computer and then used as loose guides to develop a three-dimensional line drawing that traced through the principal lines of the smoke. I extruded a circular cross section along each of these lines, producing a simple tubular structure, as illustrated in figure 4.

The key issue of this stage was deciding what, in fact, constituted the principal lines of the smoke. For some of the simpler forms, the principal lines were fairly evident. Several of the smoke forms, however, were considerably more complex, and the process of deciding what was important was quite demanding. Figure 6 is another of the smoke sculptures that was developed for this series, which illustrates the greater complexity that some of them displayed. The process of deciding which of the movements was important for forms like these was the same difficult process any artist goes through in abstracting a meaningful composition from the superabundant complexity of nature.

figure 7

figure 3

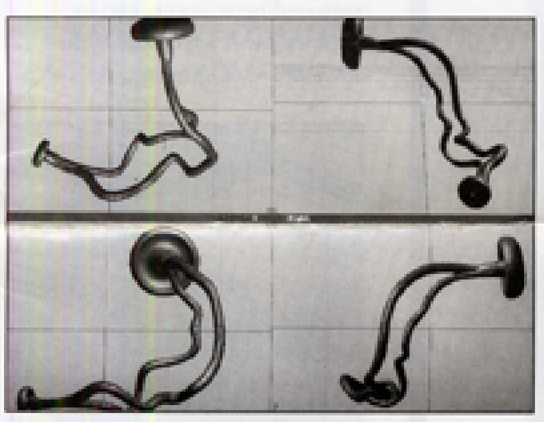

figure 4

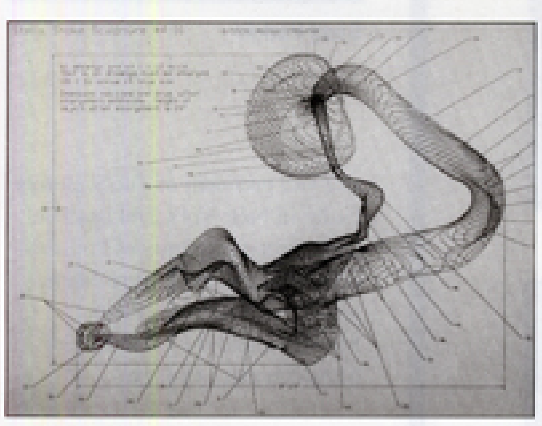

figure 5

figure 6

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Left, figures 3–6: One of the photographs of smoke that served as the starting point for the digital form in figure 2.

A circular cross-section was extruded along "principal lines" of the smoke form. Symmetrical whorls were modeled at each end using a technique that simulates a lathe.

A plotted drawing showing all of the cross-sectional curves, as seen from the top, for this smoke sculpture.

Another, more complex example of a digitally modeled smoke sculpture. The irregular surfaces of this form were developed from a simple tubular structure similar to the one in figure 4.

Above right: Frank Stella, *Toul*, 1992. Stainless steel and bronze, 18 x 20 x 18 in. The snaking form extending across the top and to the right of the piece is another smoke form modeled by the author, this time fabricated using a foam cross-sectional technique. Photo: Steven Sloman.

All images courtesy Frank Stella.

Once a basic tubular structure had been developed, its surfaces were pulled, pushed, twisted and deformed to yield a more interesting and fluid pattern of surfaces, still remaining faithful, however, to the principal lines of the original. Figure 2, which we have already seen, illustrates the results of this kind of deformation on the tubular structure of Figure 4. It is interesting to note here that what made this step (certainly one of the most important of the whole process) possible was a bug in the software package I was using. It turned out that if a surface was stretched in a certain way and then undone, the surface did *not* return, as it was supposed to, to its prestretched form, but instead settled into some unpredictable and very irregular deformation. By making repeated use of this bug and saving those "mistakes," which looked good, the boring, perfectly regular tube structure was transformed into a much more interesting and irregular "smoke" form.

Having digitally modeled a form that was satisfactory, the next step was somehow to get the data out of the computer and into the real world—in other words, to build it. We used two processes.

The first was the stereolithography process. This process uses a laser beam to polymerize a liquid plastic into extremely thin cross-sectional layers of a digital model. When all the cross sections are suitably hardened together, the result is a plastic maquette of the sculptural form. We used this technique for several of the smoke forms. Once a plastic stereolithography maquette was produced, it was given to Stella's foundry where a mold was made and cast in various metals. The two smoke forms of figure 1 were produced this way.

The advantage of the stereolithography process is that it produces extremely accurate models very quickly. The process works directly from the digital data to a precision of several decimal points, and the cross-sectional slabs are quite thin, generally the thickness of a fingernail. There are several significant disadvantages, however.

One disadvantage is size. The liquid polymer used in the process is contained in a vat, and the size of the vat limits the size of the model you can produce. Vats tend to be cubes between 10 and 20 inches. The models we made were about 10 inches in their longest dimension. In principle, it is possible to cut your data into pieces and form each piece in a separate vat, gluing them together afterwards to produce a larger model. Given the complexity and delicacy of the forms we were dealing with, however, this was deemed impractical.

Another disadvantage is cost. A 10-inch model can cost anywhere from $1,000 to $5,000. One technique for controlling this cost, however, is quite simple. The cost of a stereolithography model is largely a function of its height within the vat. By rotating your digital data around to leave the shortest possible dimension of the form extending along the vertical axis, you can minimize the cost.

A final disadvantage of the stereolithography process is that all forms must have a consistently defined inner surface and outer surface. If we think of the cloth of a shirt as being a surface, then a shirt that is either completely right side out or completely inside out is fine. Either way, its surface is consistent. But if the shirt is turned *partly* inside out, its surface orientation is inconsistent and will wreak stereolithographic havoc.

For a sculptor, of course, "partly inside out" may produce the more interesting form, and in the case of the smoke sculpture, this was definitely so. All of the smoke forms we built with stereolithography had to be laboriously remodeled to conform to the topological constraints.

Stella's reaction to an artifact of the stereolithography process is an interesting sidelight to what happened during the production of these forms. In order to hold these complicated forms in place while they were still semi-liquid in the vat, a rectangular honeycomb structure was built by the laser beam around each piece. After the piece was cured, this honeycomb structure was cut away. Stella liked the rectangular grid pattern that was left on the surfaces of the forms as a result of this process, and he requested that it be retained. This grid pattern is visible on both of the cast metal smoke forms seen in figure 1.

In order to address the limitations of the stereolithography process, we felt it was necessary to develop an alternative process. After another round of experimentation, we developed a fabrication technique based, as was the stereolithography process, on the concept of cross sections. The first stage was to compute the cross-sectional curves for a given smoke sculpture, which were then digitally plotted onto paper. An example is seen in figure 5. Registration marks were carefully calculated and included in the plotter drawings so that each cross-sectional layer could be aligned with its neighbors. Stella's assistants then enlarged these drawings to whatever scale they wanted, transferred the patterns to industrial sheets of foam, cut the foam patterns out and glued them together to form a large-scale foam maquette of the smoke sculpture. The largest of the models built in this way was approximately 20 feet in length. Figure 7 shows a smaller-scale use of this technique.

This foam cross-sectional technique imposed none of the inner surface/outer surface restrictions of the stereolithography process. This was important because it permitted a greater freedom in the digital modeling stage. Any form that could be modeled could also be built, no matter how twisted its surfaces might be. The technique also had the advantage of being much cheaper and reusable, and it lent itself to fabrication at any scale. The disadvantage of the technique was that the cross-sectional slicing was cruder and very clearly visible. Stella again took advantage of this by turning the striations of the foam models into prominent design elements.

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