Modeling Eva Hild's Sculpture "*Wolly*"

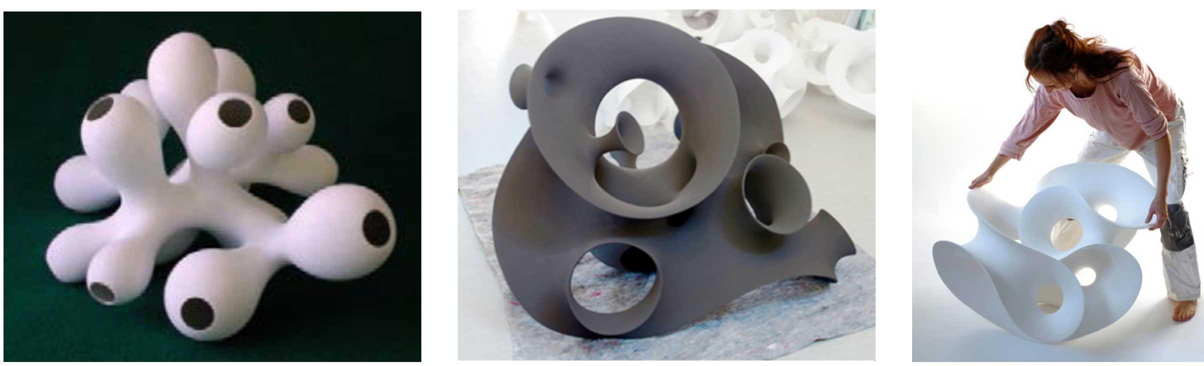
C. H. Séquin, T. Chen, X. Han, N. Jaladanki, G. Zhou
EECS Computer Science, University of California, Berkeley
Contact: sequin@cs.berkeley.edu

Abstract

Inspired by the work of Eva Hild, we have used various CAD programs and design processes to capture her undulating free-form sculpture "Wholly" in the form of a CAD model. Initial results using SLIDE, NOME, Blender and Maya are being described.

1. Introduction

Eva Hild is a Swedish artist, whose fascinating artwork can be admired on the Internet [4]. Some of her simpler, more regular sculptures are not too difficult to capture in a generic way and by exploiting symmetry as much as possible. However, Hild tries to avoid exact geometric symmetry. Here sculptures are created in a much more intuitive, free-form manner, and this results in rather "organic," free-flowing shapes (Fig.1). These shapes are more difficult to capture in a procedural computer program – particularly, if full 3D information is not available, and the only thing to start from are a few images – often from similar directions.



(a) (b) (c)

Figure 1: *Eva Hild's ceramic creations; (a) bulbous surface with oculus-like openings; (b) various nested funnels; (c) hyperboloid tunnels and undulating rims.*

(a) (b) (c) (d) (e)

Figure 2: *(a),(b) Eva Hild's "Whole"; (c) clay model; (d) skeleton CAD model; (e) 3D print.*

Figure 2 shows some re-modeling efforts on one of Hild's simpler and more regular sculptures, "Whole." Based on images found on the Internet (Fig.2a,b) a clay model was first formed (Fig.2c). With the topological understanding gained from this model, a skeletal CAD model was then created in Berkeley SLIDE [10]. Using simple sweep constructs, various rims and tunnels were placed into appropriate locations (Fig.2d). This geometry is defined by two pairs of “cross-tunnels” (shown in orange), surrounded by a 3-period undulating “Gabo-curve” (shown in green). This geometry was then exported to NOME [3][12] using a .SIF file generated in the SLIDE program. In NOME, the ribbons were connected, by interactively selecting vertices between which rubber-sheet-like quad faces were formed. This generated a crude polyhedral surface capturing the proper topology and approximating the desired geometry. This 2-manifold was then smoothed by using three levels of Catmull-Clark subdivision [2]. Finally, the smooth surface was thickened by creating two offset surfaces, and the resulting geometry was exported as an .STL file. The maquette shown in Figure 2e was fabricated on a 3D-printer *Type A* [11].

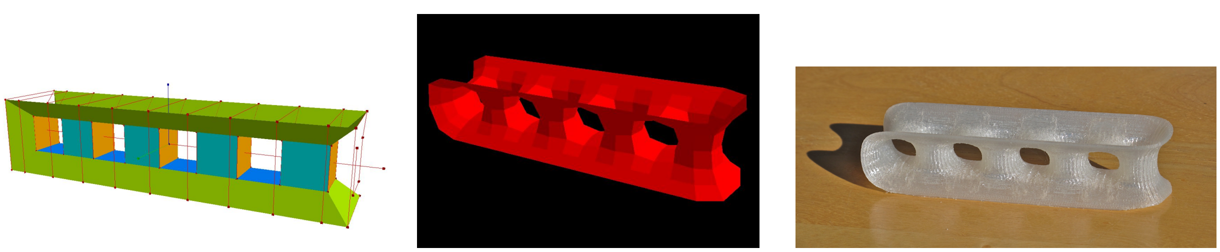
Contrary to Eva Hild’s approach, which deliberately brakes any strict, rigid symmetry and aims at a more organic look, our model maximized the potential symmetry inherent in the topology of this sculpture. This model has strict “C_{2h} symmetry” (Schönflies notation), also known as “2*” symmetry (Conway notation), featuring a vertical mirror plane (most easily visible in Fig.2d) and a horizontal C_2 rotation axis.

2. “*Wholly*”

Eva Hild’s sculpture “*Wholly*” (Fig.3), located in Borås, Sweden (2010), is a much more intricate, free-flowing 2-manifold. It would be difficult and tedious to manually place individual rings to define all eight tunnels and to model the single, long, continuous rim as an undulating 3D-space-curve. We would like to have a higher-level characterization that maintains the given connectivity, while the detailed geometry is fine-tuned visually. It turns out that the underlying topological structure of this sculpture is rather regular: it is a linear chain of alternating tunnels and saddles (Fig.4).

(a) (b) (c)

Figure 3: *Eva Hild’s “Wholly” (2010) sculpture seen from three different angles.*



(a) (b) (c)

Figure 4: *Basic topological shape of “Wholly”: (a) as a CAD model, (b) after two levels of subdivision. (c) corresponding maquette made on a 3D- printer.*

3. Preliminary Modeling Attempts (C. H. Séquin)

Deforming the Box Structure

Starting from a topological model (Fig.4) it should be possible to arrive at a good reproduction by applying local deformations. But it would still be overwhelming to ask the user to move all individual vertices of the model shown in Figure 4a into "appropriate" locations to recreate "Wholly." – We need a higher level of control.

In a first attempt, I defined 9 cross sectional planes, 7 of which go through the walls between pairs of adjacent tunnels, and 2 more are located at the ends of the chain. Each of these section-frames can be non-uniformly stretched, rotated, and shifted. A result of such coordinated edits is shown in Figure 5a. Each of the nine cross sections remains planar and symmetrical, and their sizes and positions define the shapes and orientations of the tunnels between them. The shape shown Figure 5b starts to show the flavor of Hild's "Wholly" sculpture.

But with the modeling approach described above, it was actually quite difficult and tedious to obtain good results. Often the tunnels were squashed into narrow slits, and the undulations of the rim often ended up in sharp cusps (Fig.5c). With a first, not very successful model in hand (made on an inexpensive 3D printer), it became clear, where potential modeling problems might arise. With some more carefully fine-tuning of the polyhedral model, I was able to obtain a nicer looking model (Fig.5d). Clearly, there was an improvement; -- but with this approach, it is still difficult to make the tunnels really round!

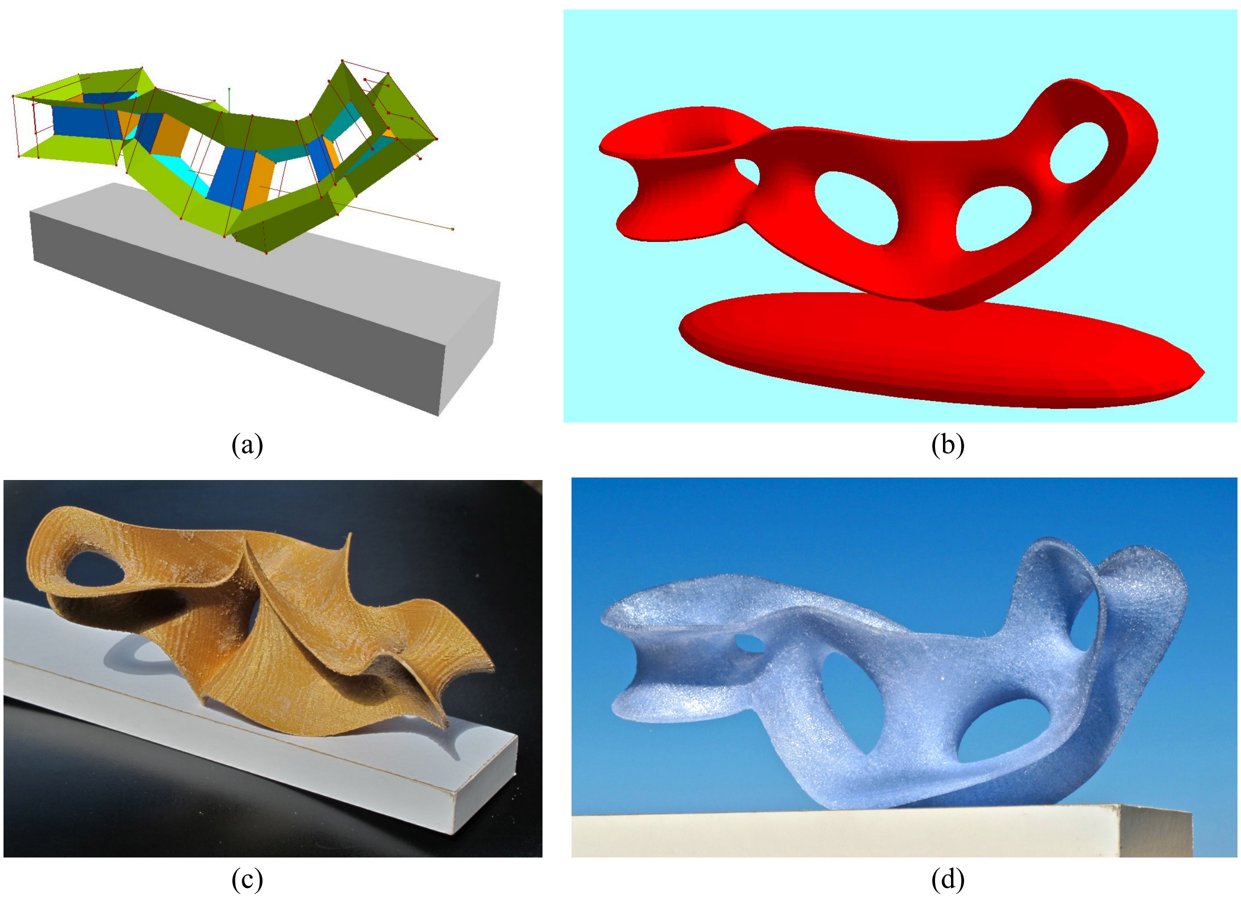
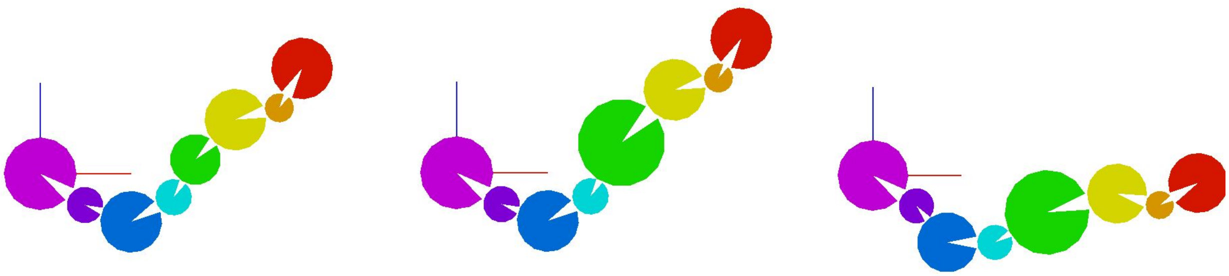


Figure 5: *"Wholly" modelled with the box-model of Figure 4: (a) deformed CAD model, (b) after subdivision smoothing, (c) very first 3D-print, (d) after more careful fine-tuning of all parameters.*

Chain of Tori or Clamps

In a second modeling approach, I started with primitives that assure that the tunnels stay nicely rounded. The new approach directly manipulates eight parameterized circular tunnels, which are the inner parts of tori, and which thus remain nicely rounded. The programs allows one to vary the sizes and angles between subsequent toroidal elements, and the program keeps neighbors in appropriate contact.

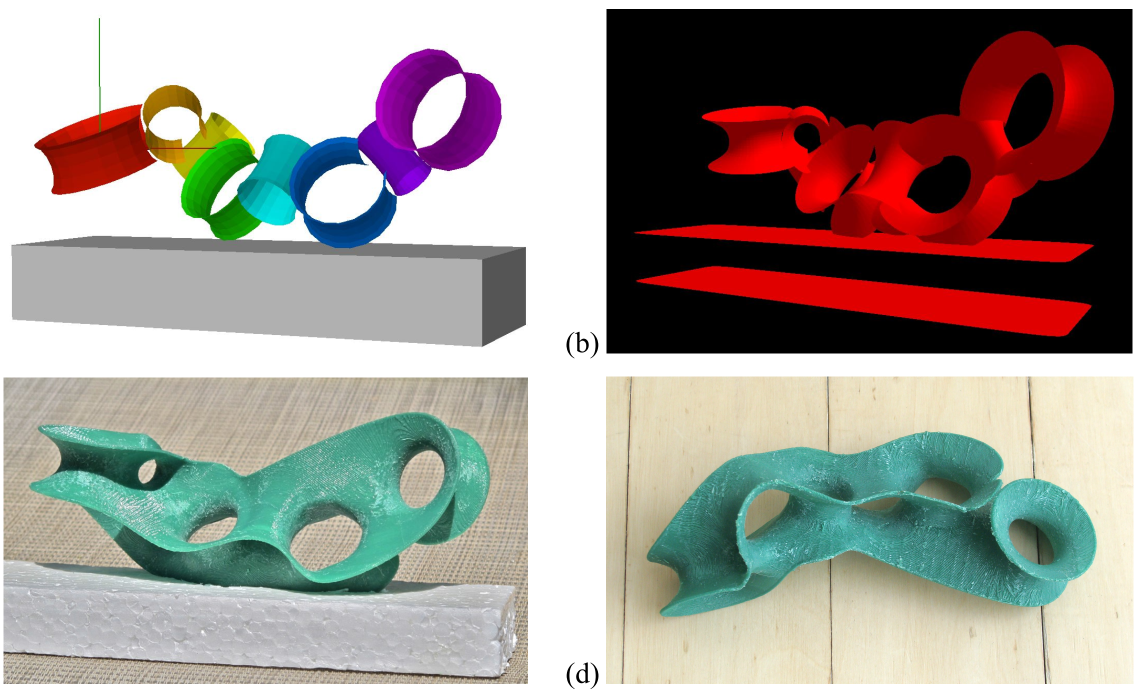
Figure 6 is a simple 2D demonstration to illustrate this concept. The user can adjust the azimuth angle and radius of any of the eight circles. From Figure 6a to 6b, the radius of the green circle has been increased. From Figure 6b to 6c, the azimuth angle of the blue circle has been changed.



(a) (b) (c)

Figure 6: *Parameterized chain model in 2D: (a) arbitrary start, (b) enlarged green disk, (c) rotating the tail of the chain starting with the blue disk.*

This approach is now applied in 3D to a chain of toroidal elements. Each toroid can be stretched in diameter and in height and can be attached to the previous one in the chain with two parameterized angles. Figure 7 shows the emerging 3D CAD model. Figure 7a displays the eight toroidal elements as the parameters defining their radii and heights, and the angles between adjacent ones are fine-tuned. Figure 7b shows the resulting surface after the eight elements have been connected and subjected to a few steps of Catmull-Clark subdivision [2].



(a) (b) (c) (d)

Figure 7: *"Wholly" modeled as a chain of toroids: (a) CAD model; (b) after two levels of subdivision; (c) resulting 3D-print; (d) backside shows a problem with the merger of adjacent toroids.*

Figure 7c shows the resulting 3D-printed model. From the front it resembles the Hild sculpture fairly closely. However, on the backside a problem is revealed: three adjacent tunnel elements are merged only incompletely, and the rim breaks into multiple loops (Fig.7d). This is indeed a difficulty with this approach. It is not trivial to merge cleanly the geometries of adjacent tunnels that share a wall between them.

4. Modeling with Commercial CAD Tools

During the academic year 2017/18, as part of a URAP group effort, we studied ways in which this flamboyant free-form shape could be modeled in Blender [1] and in Maya [7]. Below are descriptions of the modeling approaches studied by four different students.

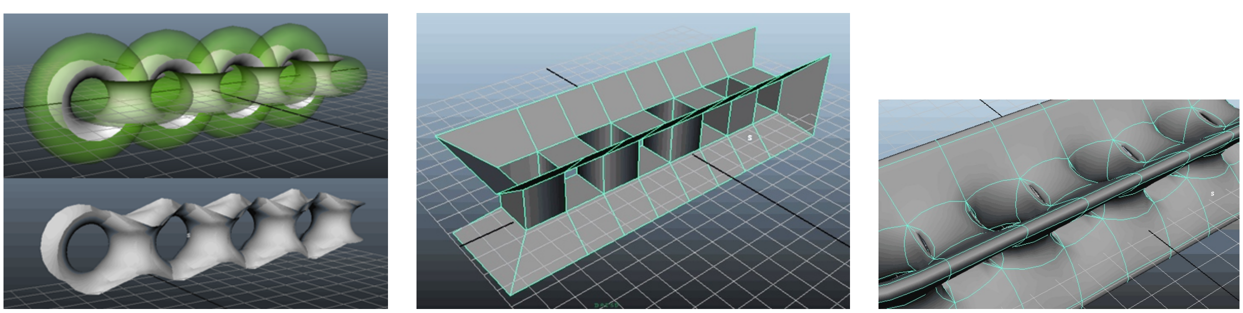
Blender: Skeletons (Toby Chen)

<not yet ready, omitted>

Maya: Cross-Shaped Skeleton (Kathy G. Zhou)

My initial approach was to construct a topologically correct model formed from some basic units. I chose this unit to be the inner half part of a torus that had a major radius twice its minor radius. I placed four of them next to one another, so their toroidal arms would overlap, and a second set of four to pass through the holes of the first chain (Fig.K1a, top). After removing some unneeded facets, a structure reflecting the desired topology emerged (Fig.K1b, bottom). However, this CAD model still comprises a large set of chaotically overlapped faces – far from the desired, clean 2-manifold structure.

In a second attempt, I started from a cuboid whose width, height, and length followed the ratio 1:1:8. After removing unneeded facets, I added additional square facets to form the interior walls between adjacent tunnels (using the "append to polygon" tool) and also extruded the outer edges diagonally (Fig.K1b), arriving at a structure very similar to the one shown in Figure 4a. While adding faces to the middle of the cuboid, it was really important to make sure that all four sides of the quadrilateral were connected to the cuboid. Therefore, it is much better to use the "fill hole" tool, rather than using the "append to polygon" tool, which only connects two sides. The flaws of using the "append to polygon" tool became obvious after I gave the surface some thickness via an offsetting operation (Fig.K1c).

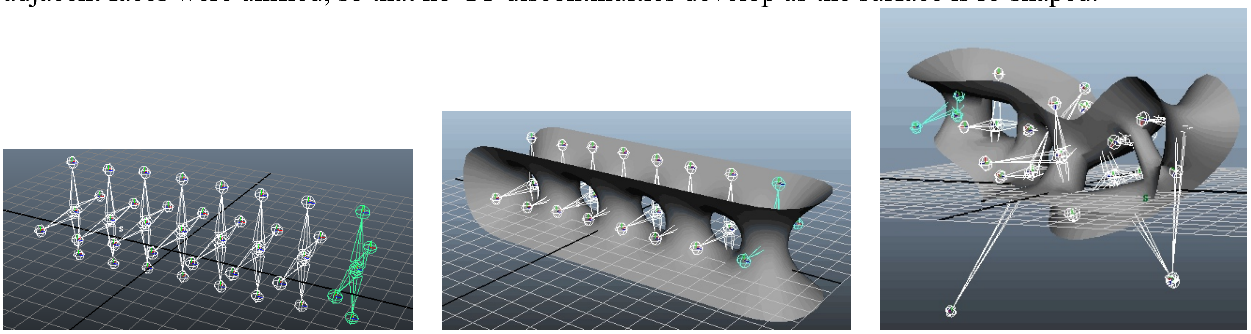


(a) (b) (c)

Figure K1: *Starting geometries: (a) coupled tori, (b) collection of cuboids, (c) connectivity problems.*

The next step was to find a way to change the geometry of this shape to make it look more like "Wholly." While a brute-force adjustment of every individual vertex is always a possibility, this would be a very tedious and time consuming approach. Maya, offers a function under the "skeleton" category that adds "joints" that can then be bonded to the model like bones supporting skin. I experimented with several ways to add bones to my model and found that the one shown in Figure K2 worked best for this sculpture.

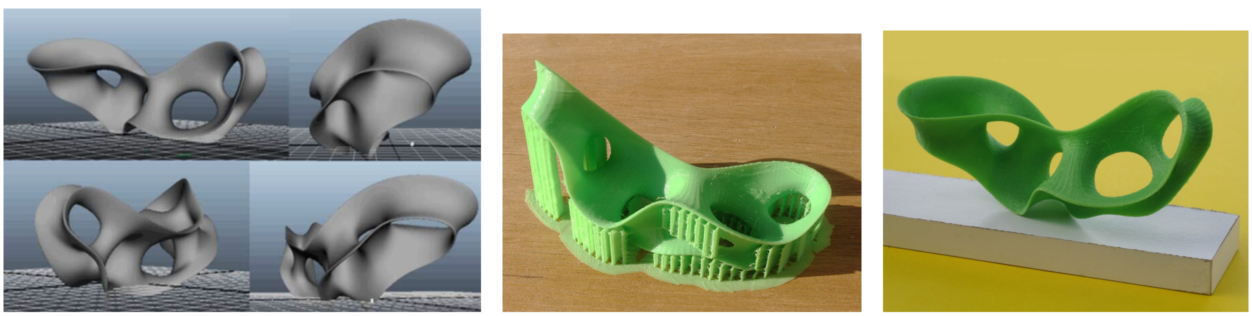
I used eight separate cross-shaped bones (Fig.K2a,b) that could be rotated, scaled, and displaced individually, thereby deforming and repositioning each tunnel of the model as a whole, while keeping the surface properly connected. After using the skeleton to put the tunnels roughly in place (Fig.K2c), I manually adjusted some vertexes to make the rim as close to "Wholly" as I could, based on a limited number of pictures. An important point was to make sure that the direction of the vertex normals between adjacent faces were unified, so that no G1-discontinuities develop as the surface is re-shaped.



(a) (b) (c)

Figure K2: *Skeleton: (a) 8 cross-bones, (b) coupled to the 8 tunnels, (c) geometrically adjusted.*

Eventually, I derived a final version of "Wholly". Figure K3a shows the model from different angles after it had been given some thickness, as well as a maquette built from an exported .STL file.



(a) (b) (c)

Figure K3: *"Wholly" (a) CAD model, (b) 3D-print, (c) cleaned maquette, properly positioned.*

An interesting note concerning this design effort: Finding out **what** to model was just as difficult as knowing **how** to model it. We started out with only four different views of this sculpture. Additional views then lead to substantial changes in the model. I clearly remembered starting all over again, after receiving one more picture from professor Séquin. But, all in all, the process of constantly upgrading my model using different approaches was quite an enjoyable experience.

Maya: IK Handles on Skeleton (Jessie X. Han)

<not yet ready, omitted>

5. Summary and Conclusions

It is certainly a good thing to have some armature composed of skeletal bones or of an embedding lattice to fine tune the geometry of a mesh. However, defining this armature based on a coarse topological model that is far off from the desired geometry is not so useful and may result in a rather contorted control structure. It works well, when the armature is closely tied to the final geometry and only used to make small local geometry adjustments.

It thus seems preferable to start with a parameterized compositional description that creates a first model close to the desired target geometry, as described in the first half of this report. Then an effective, easy-to-use armature can be constructed on that model. Perhaps that first, properly parameterized model itself could be used as the armature. To test this concept, the emerging NOME software currently under development should be enhanced with a mechanism that allows the merged mesh to be subjected to localized, smooth deformations by dragging any mesh-point around interactively and have the influence of this deformation fall off radially with some user-settable influence radius.

Acknowledgements

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