Flat-Foldable Axisymmetric Structures with Open Edges

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Some objects (such as cases or tents) have the important property of being flattened into a 2D configuration for storage purposes. These structures have a 3D shape that gives them some functionality, but can also be compacted when not used.

In this paper, we propose a method to design axisymmetric structures that can be folded flat with thickness. The flat configuration of the model is obtained by pushing the structure downwards. Our model is represented by a polyhedron with a vertical symmetry axis. The edges that are not coplanar to the axis are hinges that connect two faces allowing their dihedral angle to change. The other edges are open during the folding process, binding two faces only in the original 3D configuration.

The design interface consists in using mouse clicks to input an arbitrary outline formed by connected line segments. This outline is the desired axial cross section of the model. Usually, the input produces structures that are not flat-foldable and, therefore, we have to adjust the length and position of the line segments to enable flat-foldability (Fig. 1). This is an optimization process, changing the outline the minimum possible. In this process, we introduce evaluation values related with the folding process in order to make it easier by avoiding changes in the fold direction of hinges. Then, we add thickness to the optimized outline. Finally, we output the data of a flat-foldable model, the assignment of fold directions and the 3D animation of the folding process. (Fig. 2).

The results show that our design method is capable of generating flat-foldable structures. Figure 3 shows a real model constructed using the results shown in Figures 1 and 2.

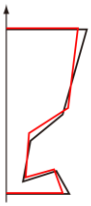

Figure 1: Original outline input (black) and the modified flat foldable outline (red).

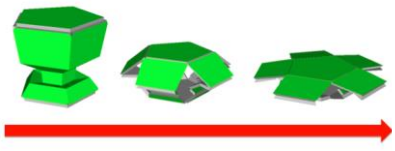

Figure 2: Animation of the folding process.

Figure 3: The real model built with 3D printer.