Supplementary Material

Cost-effective Printing of 3D Objects with Skin-Frame Structures

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● Illustration of our algorithm on 2D case

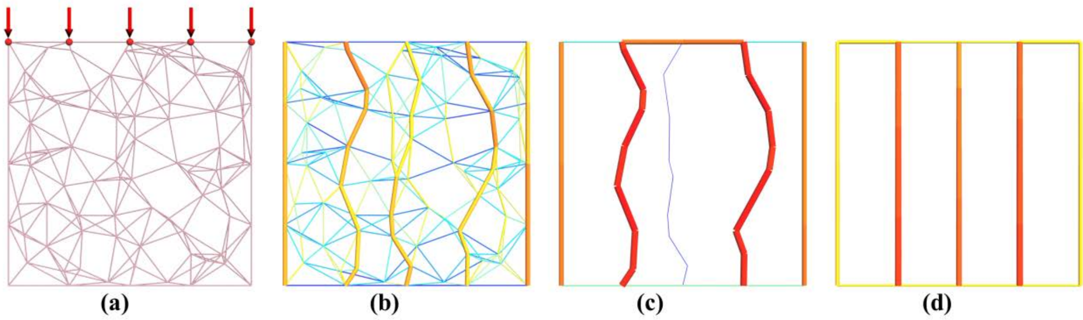

Figure 1: *Pipeline of our algorithm on 2D case. (a) is the initial sampling, connectivity and external forces; the initial truss is generated with (b); (c) and (d) are the topology optimization of our algorithm*

● Comparisons of the supporting structures on FDM printers

Figure 2: *Extrusion-type (FDM) 3D printers need to add extra supporting structures to print the objects. (a) shows the printed result with supporting structure generated by the naive method in commercial software; and (b) shows the printed result with supporting structure generated by our method. It is seen that our method needs much less material used in the supporting structures.*

Detail of the Balance constraint in Section 3.2

To make the printed object self-balanced while standing on a horizontal plane, the vertical projection G_{proj} of its mass center G onto the plane should lie within the convex hull H of its contact points on the plane [Prevost et al. 2013]. That is, the balance constraint is as follows:

$$G_{\text{proj}} \in H \,.$$

1) Calculate the mass center of the object

In order to calculate the mass of the object, we tetrahedralize the skin layer into a set of tetrahedron elements $\{T_i\}_{i=0}^{n-1}$. Then the mass and mass centers of the tetrahedrons can be obtained as $\{m_{T_i}\}_{i=0}^{n-1}$ and $\{c_{T_i}\}_{i=0}^{n-1}$ respectively.

Denote $\{l_i\}_{i=0}^{m-1}$ as the set of all struts. As each strut is a cylindrical shape, its mass and mass center can be easily computed. Denote $\{m_{l_i}\}_{i=0}^{m-1}$ and $\{c_{l_i}\}_{i=0}^{m-1}$ as the mass and mass centers of all struts respectively.

Then the mass center of the object is calculated as follows:

$$G = \frac{\sum_{i=1}^{n}(c_{T_i} * m_{T_i}) + \sum_{i=1}^{m}(c_{l_i} * m_{l_i})}{\sum_{i=1}^{n} m_{T_i} + \sum_{i=1}^{m} m_{l_i}} \,.$$

Then the vertical projection of G onto the standing plane can be computed as G_{proj}.

2) The balance constraint

Suppose H has k vertices $\{P_i\}$ (i = 0,1,..., k-1) in the clockwise order in the standing plane. Then the balance constraint is represented as follows:

$$(P_i - G_{\text{proj}}) \times (P_{(i+1)\%k} - G_{\text{proj}}) < 0, \qquad i = 0,1,\ldots,k-1.$$