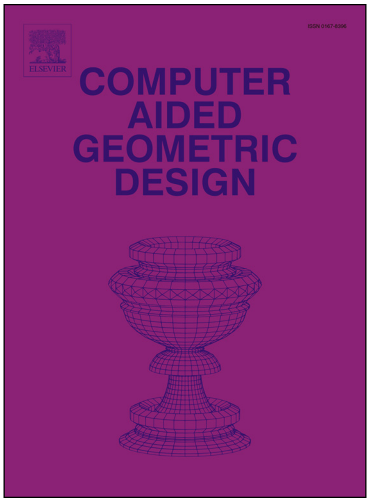

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Generating Hybrid Interior Structure for 3D Printing

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Abstract

Generating an interior support structure is a key issue in 3D model geometric optimization for 3D printing. Most existing interior support structures have been designed by simulating lightweight structures naturally exist. One limitation of the existing method is that only one single structure is used for the model. However, different parts of a 3D model have different shapes and mechanical properties and different structures demonstrate distinctive advantages for supporting the model. Based on such observation, we propose to use hybrid structures for designing an optimal support structure. In this paper, we present a novel scheme of generating hybrid interior support structures for 3D printing. The proposed approach first partitions an input model into parts with different physical behaviors. Different interior structures are generated for each part, and the interior structures are finally joined together. Experimental results demonstrate that the proposed hybrid structure obtains higher strength-to-weight ratio than recent competing approaches that use single types of interior structures.

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1 Introduction

3D printing techniques have recently become popular due to its powerful ability and flexibility in manufacturing complex 3D shapes. In addition to providing a flexible solution in manufacturing personalized product, 3D printing has also been used in many scientific and industrial applications, e.g., aircraft design, medical structures printing, or even personalized medical support. However, 3D printing also suffers from several practical challenges, such as speed, waste of support material, stability and physical behavior of the printed objects.

One of the most important issues in 3D printing is establishing physically printable and usable prototypes by using less material. The printing material is used in two aspects, one is for the printed object (the shell and infill), and the other is for exterior support structure that must be polished after printing. The material for support structures can be reduced either by selecting better printing orientations or designing smart lightweight support structures. However, the infill structure greatly influences the quality of the printed objects, e.g., strength, stability, and material usage.

Generating infill is a common practice of simulating lightweight structures in nature to obtain high strength-to-weight ratio [31, 16]. Many elegant interior structures have been designed to save materials while retaining the physical properties (see Sec. 2). Existing works focused on designing a single structure inside the volume of the object. However, different structures exhibit distinctive advantages for different stress distributions. For example, the muscle fiber structure has significant directional (anisotropic) stress intensity, whereas the crystal structure has uniform (isotropic) stress intensity in all directions. Filling an isotropic space with fiber structure might cause significant material waste. In this work, we propose to use different structures in regions with different stress behaviors.

In our approach, an input 3D model is first partitioned into different components based on their shape and stress distribution. A part of shape can be classified as anisotropic and isotropic with respect to their physical behavior. An anisotropic region always exhibits column-like (Col) structure, whereas an isotropic region has non-column (NCol) structure. The Col components are further validated through mechanical analysis. The components that passed the validation are further classified as valid Col (VCol) structure. Therefore, we focused on these two types of components. One is VCol component with high stress in the axial direction and the other is NCol component. The interior support structure of the VCol component is generated using the *muscle fiber structure* (MFS), whereas its NCol component is formed using the *tetrahedral crystal structure* (TCS). Furthermore, transient structures are generated at the interface between the components. These structures are designed to preserve the connection between neighboring components.

The contribution of our work is two-fold. First, we demonstrated that hybrid interior support structures are suitable for various 3D models in 3D printing. We also developed a strategy to partition the 3D model to match different structures with specific shape and mechanical properties. Second, we designed two specific structures, MFS and TCS, to generate hybrid structures in 3D models that can be partitioned into Col and NCol components. We also designed transient layers for connecting MFS and TCS to generate a complete hybrid interior support structure for a 3D model.

2 Related Work

Many works have been conducted on different stages of 3D printing pipeline [14]. The major challenges of 3D printing techniques include the issues in efficiency, strength, material usage, and physical behavior of the printed objects [4]. In this section, we briefly discuss the representative works and then emphasize on the problem of interior structure design with the aim of using less material while retaining the strength of the printed objects. More comprehensive discussion can be found in the recent survey papers [13, 27].

To print large objects, several approaches addressed the problem of decomposing the input models into printable parts [8, 17, 9, 5, 24, 10]. To enhance the physical strength, Stava et al. [25] and Zhou et al. [44] proposed to thicken the weakest part of the model. Umetani and Schmidt [26] optimized the printing process by analyzing the stress of cross sections. Wang et al. [28] optimized the structure by considering the force from any direction instead of only one direction. The efficiency of the printing