Numer. Math. Theor. Meth. Appl. Vol. **13**, No. 4, pp. 845-862
doi: 10.4208/nmtma.OA-2019-0199 November 2020

Uniformly Distributed Circular Porous Pattern Generation On Surface For 3D Printing

Sungha Yoon[1], Chaeyoung Lee[1], Jintae Park[1], Darae Jeong[2] and Junseok Kim[1,*]

[1] *Department of Mathematics, Korea University, Seoul 02841, Republic of Korea*
[2] *Department of Mathematics, Kangwon National University, Gangwon-do 24341, Republic of Korea*

Received 30 December 2019; Accepted (in revised version) 10 March 2020

Abstract. We present an algorithm for uniformly distributed circular porous pattern generation on surface for three-dimensional (3D) printing using a phase-field model. The algorithm is based on the narrow band domain method for the nonlocal Cahn–Hilliard (CH) equation on surfaces. Surfaces are embedded in 3D grid and the narrow band domain is defined as the neighborhood of surface. It allows one can perform numerical computation using the standard discrete Laplacian in 3D instead of the discrete surface Laplacian. For complex surfaces, we reconstruct them from point cloud data and represent them as the zero-level set of their discrete signed distance functions. Using the proposed algorithm, we can generate uniformly distributed circular porous patterns on surfaces in 3D and print the resulting 3D models. Furthermore, we provide the test of accuracy and energy stability of the proposed method.

AMS subject classifications: 65D18, 68U05

Key words: Diblock copolymer, porous surface, 3D printing, nonlocal Cahn–Hilliard equation.

1. Introduction

Three-dimensional (3D) surface models have been studied with great interest in various fields. For this reason, design, synthesis, deformation, and transformation on surface mesh for 3D fabrication have been studied [7, 27, 30]. Typically, 3D printing technology is used in medical fields. Because making 3D models should be not only

*Corresponding author. *Email addresses:* there122@korea.ac.kr (S. Yoon), chae1228@korea.ac.kr (C. Lee), jintae2002@korea.ac.kr (J. Park), cfdkim@korea.ac.kr (J. Kim), tinayoyo@kangwon.ac.kr (D. Jeong)

economic but also hygiene in medical field applications, additional remeshing methods are required. Likewise, additive manufacturing techniques such as representation and optimization are also important for printing actual 3D models [3, 14, 28, 33]. In particular, 3D surface with porous pattern is a representative example of complex structures [16]. Having porosity has many advantages in various fields: biomaterial, tissue engineering, and clinical medicine, etc. However, a large amount of data is required to represent such complex shapes, which requires more computational time. For this reason, it is important to remesh the surface of 3D model. There are various strategies to remesh surfaces. The authors in [40] used an electrospinning and 3D printing technology to fabricate a 3D composite structure. The authors in [26] showed a durable superhydrophobic porous surface can be used to separate two fluids, oil and water, using a 3D printing. Jakus *et al.* [17] introduced a procedure using extending 3D printing technology and traditional salt-leaching to make 3D print materials and structures with high porosity. These methods used 3D printing technology, however, only created basic surfaces or structures, and it was difficult to apply it on complex surfaces. Another widely used example of creating porous surface is the Voronoi diagram. Pellerin *et al.* [29] and Valette *et al.* [36] used a remeshing method based on the Voronoi diagrams with the finite element method. Chaidee *et al.* [6] generated spherical Laguerre Voronoi diagrams for approximating spherical polygonal tessellations. In [2], the authors presented a surface modification method to make 3D models which are shaped with Voronoi and fractal diagram surface. In medical manufacturing field, to make a comfortable and aesthetically orthopedic casts for patients without sacrificing any of its functionality, a funnel-shaped cast model was proposed in [25] and it can create smooth edges to prevent bruises from movements of injured limbs. Furthermore, different structures of orthopedic casts such as non-uniform Voronoi, regular cell, mesh edges pattern were designed on the surface by different technical methods. In [13], the authors proposed a low-cost 3D scanning and used computer-aided design (CAD) software to generate different structures of orthopedic casts as shown in Fig. 1.

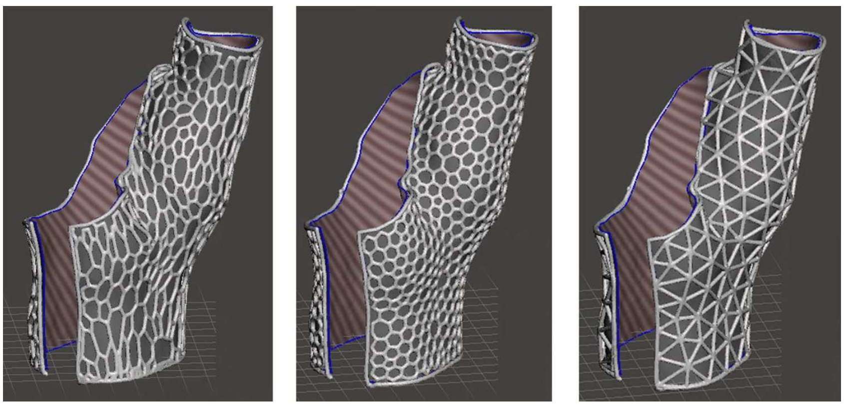

Figure 1: Different structures by using Autodesk Meshmixer free software. Reprinted from Fernandez-Vicente et al. [13] with permission from Rapid Prototyping Journal.