Stochastic Geometry for Bio-Medical CAD

Extended Abstract

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Heterogeneous solid modeling is an emerging area with wide-spread applications in computer-aided design, manufacturing, bio-medicine and geo-physics. Existing research on heterogeneous modeling has focused primarily on the needs of the manufacturing processes solid free-form fabrication, usually with the goal of improving the fidelity of the manufacturing process to produce usable parts, rather than mere prototypes. Other researchers have studied how to model material gradients and multi-material objects.

In our work, we are using *stochastic geometry* to both represent and model three-dimensional (3D) objects with varying surface, internal and volumetric properties and geometries—with a specific application to bio-medical structures. The field of stochastic geometry is mathematically rich and diverse, but it uses thus far have not included computer-aided design and manufacturing. Considerable recent work in stochastic geometry has focused on geophysics (i.e., simulation of geological structures for oil exploration) or telecommunications (i.e., analysis of interference patters and distributions of cellular communications towers). Historically, stochastic geometry has been used to study a diverse array of physical phenomena including the distributions of fault lines, scattering of alpha particles and the conflagration created by exploding aerial bombing.

This presentation will give a general overview of stochastic geometry and provide a detailed example of how it can be effectively used for design, modeling and (eventually) fabrication. Specifically, our work uses a stochastic point process to represent the internal porosity of an object. While much work in heterogeneous modeling has focused on object density, this is quite different from the internal representation of object porosity. While density is a general property of a model's interior, porosity refers to the specific geometry of the inside. For example, a model with high density might have a single large pore or many infinitesimally small pores. Conversely, a model with low density might have a porous structure much like that of the human bones, where the pore sizes are relatively consistent and result in a highly connected internal structure. Hence, given a fixed model density, the specific internal porous geometry could vary greatly depending on the statistical distributions that describe the locations and sizes of the pores.

We will describe some of the modeling operations these representations can be used to perform and show empirical results based on the technique. We will also discuss the potential impact for broadening and deepening the connection between the ideas of stochastic geometry and those of the traditional computational geometry community.