Accelerating 3D printing for surface wettability research

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Summary

The wettability of a surface is affected by its physical and chemical properties, but it can be modulated by patterning it. Researchers use many different techniques for surface patterning, each one with different trade-offs in terms of cost, flexibility, convenience and realizable geometries. Very high-resolution 3D printing technologies (such as stereolithography by two-photon absorption) have the potential to greatly increase the range of realizable surface geometries, but they are currently not in wide use because they are too slow for printing the relative large surface areas required for wetting experiments. To enable the use of these 3D techniques, we are developing new slicing algorithms able to speed up 3D-printing technologies.

Keywords: 3D printing, slicing, two-photon absorption stereolithography

1. Introduction

It is widely known that careful patterning of a surface can modulate its wettability to a significant extent, and that features at several different length scales can contribute to this effect [1]. While there are many different techniques for applying patterns to a surface, we are interested in leveraging very high-resolution 3D printing technologies, such as stereolithography by two-photon absorption (TPA) [2], which reliably enables the manufacturing of surface geometries impossible to achieve with other technologies, at resolutions in the range of a few hundreds of nanometers.

TPA stereolithography acts by moving a focused infrared laser relative to a space filled with photosensitive liquid resin. Upon exposure to the focused laser, the resin polymerizes. While very small features (in the order of a few nanometers) can be crafted in carefully arranged experiments [3], the effective, repeatable resolution is a function of laser power, exposure time and the size of the laser focus, and ranges from several micrometers to a few hundreds of nanometers [2].

A surface pattern large enough to conduct wetting experiments over it is typically within one order of magnitude of one square centimeter. Because of this, it is currently impractical to use 3D printing technology for wettability research. To print a suitable surface pattern at very high-resolution (hundreds of nanometers), the required time is too big, in the range of several days to a few weeks. The printing time can be drastically reduced by printing at lower resolutions, because the volume subtended by the laser focus is considerably bigger at lower resolution, but possibly relevant features at the sub-micrometer scale are lost.

A natural way to solve this dilemma is to use different resolutions to manufacture the surface. In fact, this idea has already been explored [4-7], but in almost all previous research, the user still has to manually consider the object or pattern to be manufactured, analyzing it in order to decide what parts are to be generated at each resolution. While this is feasible for simple objects and patterns, it quickly becomes impractical when it comes to more complex ones, such as surface patterns obtained from real-world objects by profilometry. Also, some methods have been published to analyze 3D models automatically and decide which parts are to be manufactured at each resolution, but they are either too simple [8], or suitable only for very simple 3D objects or patterns [9].

What is really needed is an automated way to combine manufacturing processes at different resolutions. And this is the crux of the problem: current engineering practices for 3D printing technologies implicitly assume

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that objects are to be printed at one resolution, and all the software and the underlying algorithms are geared towards the use of a single resolution, even if the underlying technology can print in a wide range of resolutions. To make a more effective use of 3D printing technologies, we are developing new algorithms that are able to analyze a 3D computer model of the surface to be printed, and determine which parts of the model can be printed at different resolutions. In this way, the bulk of the surface can be quickly printed at low resolution, while only the small details have to be printed at high resolution, dramatically speeding up the printing time. To illustrate this graphically, Figure 1 shows a fractal surface, which has features at several scales. Figure 2 shows the result of processing this surface with our algorithm: red lines represent toolpaths at low resolution, and green lines toolpaths at high resolution.

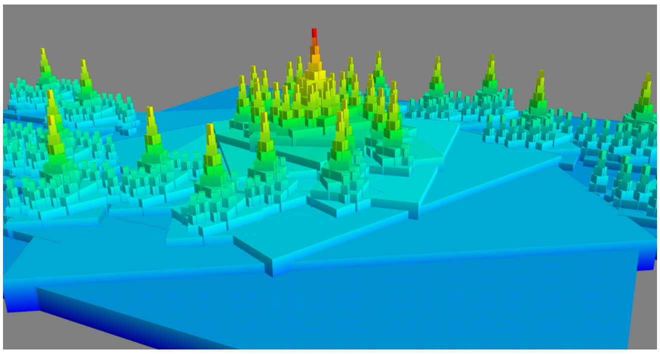

Figure 1

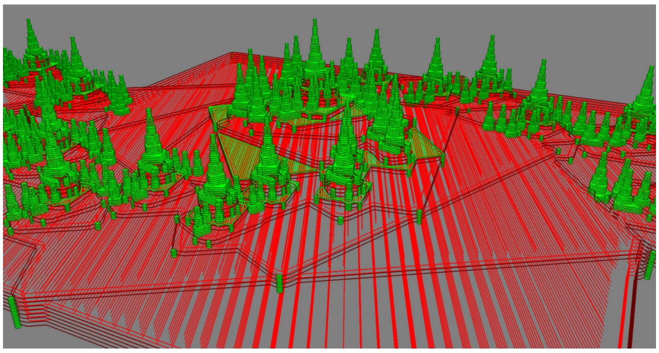

Figure 2

We are currently adapting our software to work with different manufacturing processes, such as micromachining by femtosecond laser and TPA stereolithography. In fact, our algorithms are quite flexible: they can be used to combine manufacturing processes of different natures (additive / subtractive), and have been designed to be able to correct for manufacturing errors, if a suitable way to measure these errors (such as taking accurate, high-resolution topographic images of the surface under construction) is available.

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