Method of 3D Printing Micro-pillar Structures on Surfaces

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ABSTRACT
This work presents a method of 3D printing hair-like structures on both flat and curved surfaces. It allows a user to design and fabricate hair geometry that is smaller than 100 micron. We built a software platform to let one quickly define a hair's angle, thickness, density, and height. The ability to fabricate customized hair-like structures expands the library of 3D-printable shape. We then present several applications to show how the 3D-printed hair can be used for designing toy objects.

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H.5.2. Information interfaces and presentation: User Interfaces

INTRODUCTION

3D printing is rapidly expanding the possibilities for how physical objects are fabricated [1]. Its Layer-By-Layer fabrication process has tremendous potential to enable the fabrication of physical objects not previously possible. Recently, high-resolution 3D printer is getting more and more available and affordable. This enables micron-scale structures to be fabricated. In this paper we present a bottom-up printing pipeline to fully utilize the capability of current high-resolution photopolymer 3D printers. This allows us to generate large amount of fine hair on 3D objects' surfaces. We introduce method for the fabrication of *Cilllia*. We then show examples of using *Cilllia* for toy design.

PRINTING HAIR-LIKE STRUCTURE

All the test and examples showing in this paper are printed on a commercially available Digital Light Processing (DLP) 3D printer (Autodesk Ember Printer). The DLP printer takes stacks of bitmap images from the CAD models, and direct project the image to the liquid resin layer by layer. This approach allows us to construct 3D object with 2D images. It also permits overhang structure within 60 degrees during printing. The printer has the feature resolution of 50 µm on X and Y axis, and 25 µm on Z axis. The build volume is 64 by 40 by 150 mm. The used print material is near UV light photopolymer (Available on //spark.autodesk.com/ember/shop).

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Challenges

Although the resolution of recent 3d printer has been improving, it is still considered impractical to directly print fine hair array on object's surface. This is due to the lack of efficient digital representation of CAD model with fine surface texture [2]. Most of the current commercially available 3D printer takes a Layer-By-Layer method to deposit/solidify materials into shapes that are designed in the CAD. It follows a Top-Down pipeline, where user creates digital 3D model, and then a program slices the model into layers for printer to print. In the field of Computer Graphics, the standard way to represent surface texture is through lofting bitmaps on the CAD model to create an optical illusion. It is not an actual 3-dimensional structure. If we were to create thousands or even more small hairs with conventional CAD system with real geometry, we will find it difficult or impractical to do: The data for describing the total geometry becomes extremely large and displaying such complex structure also takes a great deal of time

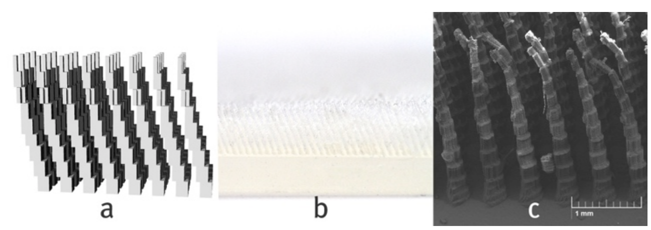

Figure 1. (a) Computer simulation of printed hair; (b) close view of actual printed hair; (c) SEM photo of the (b).

We propose a Bottom-Up 3D printing approach to design and fabricate hair-like structures without making 3D CAD models, where user directly generate printing layers that contains hair structure information for the 3D printer. Comparing to other surfaces texture such as wrinkle, hair is relatively simpler to generalize mathematically. It is usually a high aspect ratio cone that is vertical/angled to the surface. The height, thickness and profile might vary from one to another. As we know, the diameter of cone continuously decreases from the base to the tip. This method allows us to control hair printing from three aspects: 1. Single hair's geometry (1D): height, thickness, angle and profile; 2. Hair array on flat surfaces (2D): varying single hair geometry across the array on a 2D surface; 3. Hair array on curved surfaces (3D): generating hair array on any given curved surfaces.

We successfully printed a series of sample surfaces with oriented hair. Figure 1 shows that our printed geometry matches the computer simulation.

Applications

To show the capability of our printing method, we create three types of possible application for designers.

Objects with fine surface texture

As we can generate hair on any curved surfaces, we can now 3D print flowers and animals with such feature. We can also vary the thickness of the hair to control its stiffness. Figure 3 shows a hedgehog that has thicker hair (6 by 6 pixels on the base), and a bunny that has thinner one (3 by 3 pixels on the base). The hair of the latter one curls after dry due to its softness.

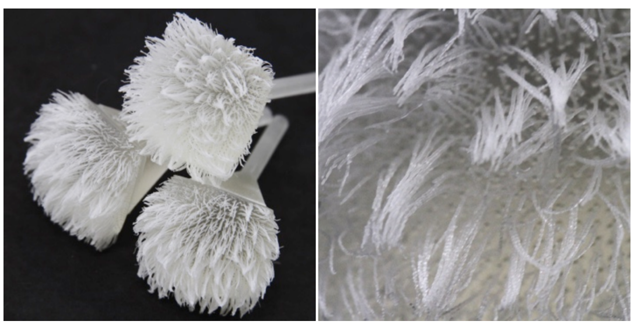

Figure 2. Successful printed hair arrays on curved surface.

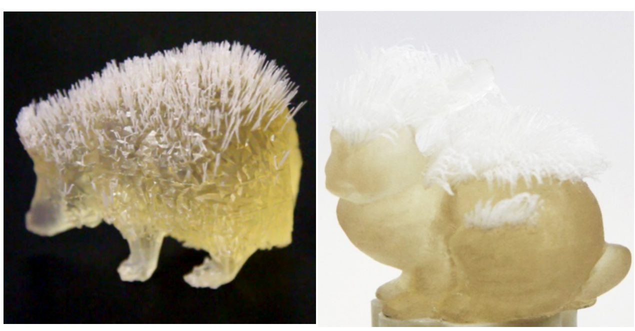

Figure 3. 3D printed figures with controllable hair stiffness.

Customized Brushes

We can also directly 3D print brushes with customized texture. Figure 4 shows four brushes with different density. With the color mapping method, one could create more complex shape of a brush for artistic expression.

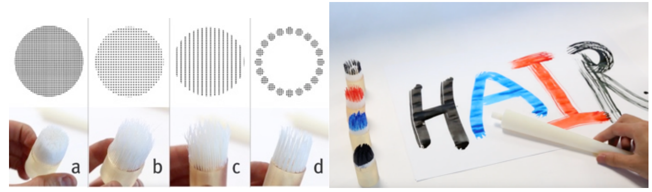

Figure 4. Printed brushes with different density.

Mechanical Adhesion

One interesting phenomenon we found during our exploration is that two panels with dense hair can tightly stick to each other when pressed their hair together. This might be because the large amount of contact surface on the hair that creates high friction. Figure 5 shows the details of the print.

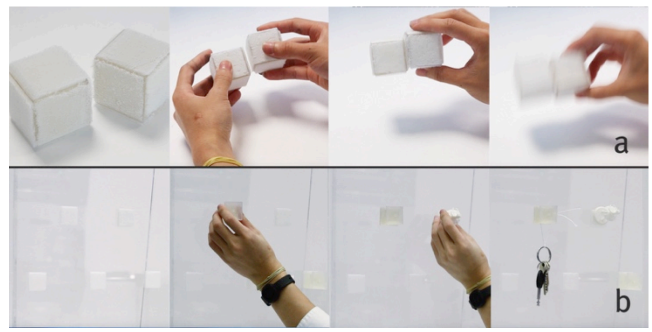

Figure 5. Printed flat surface with Cilllia with mechanical adhesion property.

CONCLUSION

We present a method of 3D printing hair-like structures on both flat and curved surfaces. It allows a user to design and fabricate hair geometry at the resolution of 50 um. We built a software platform to let one quickly define a hair's angle, thickness, density, and height. The ability to fabricate customized hair-like structures not only expands the library of 3D-printable shape, but also enables us to design alternative mechanical adhesion structures.

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