infoTexture: Incremental Interfaces on Mesh Prototyping

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Abstract
In recent years, the rapid prototyping of 3D objects has been a popular research, which mainly focusing on the fabrication process of prototypical structures and shapes. However, relatively little research has examined the surface texture of 3D models. To meet the increasing requirements of HCI researchers who are prototyping 3D forms with information on the surfaces to build multivariate interfaces, we present infoTexture, a novel rapid prototyping system that produces 3D objects both in a mesh structure and covered by a surface texture simultaneously. Based on mesh structure of 3D models, infoTexture supports a highly customizable software platform, which is applicable for seamlessly splitting freeform surface into planar pieces with a regular grid and serves as a guide for easy assembly. The key idea is to establish user interfaces on the surfaces of 3D model, which can be achieved by the programming shape of texture, the mapping pattern of texture and the interactive way with the texture.

Author Keywords
Surface texture, prototyping, 3D, UV mapping

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

At present, rapid prototyping in HCI mostly use personal fabrication tools, such as 3D printers and laser cutters, to quickly create 3D physical objects with different modelling methods. In Autodesk ® 123D ™ Make [1], a digital 3D model can be segmented into slices and spliced by plane board, but this method could not recover the surface of objects. 3D printing is an approach to produce high precision models while it is difficult to redesign or tinker on the one-off surface due to the solidified materials with a time-consuming fabrication. Compuwoven [9] is the rapid prototyping approach to constitute the surfaces of 3D models with low cost materials and flexible assembly, which could be modified immediately in the process of manual assembly. Based on this attribute, we considered the grid structure construction method as the foundation of producing surface texture to build up our system called infoTexture, which can produce 3D models covered by surface texture.

InfoTexture is proposed as a computer-aided fabrication approach that combines structures with surface texture. This approach is designed not only to achieve the advantages of fast, low cost and flexible assembly, but also to provide user interfaces on the surface of 3D models that convey information between human and object. The communication can be expressed by the programmable cross line for texture information; by the pattern mapping from 2D patterns to 3D models for visual information; and by the surface construction for an open user interfaces.

In this paper, our main contributions include:

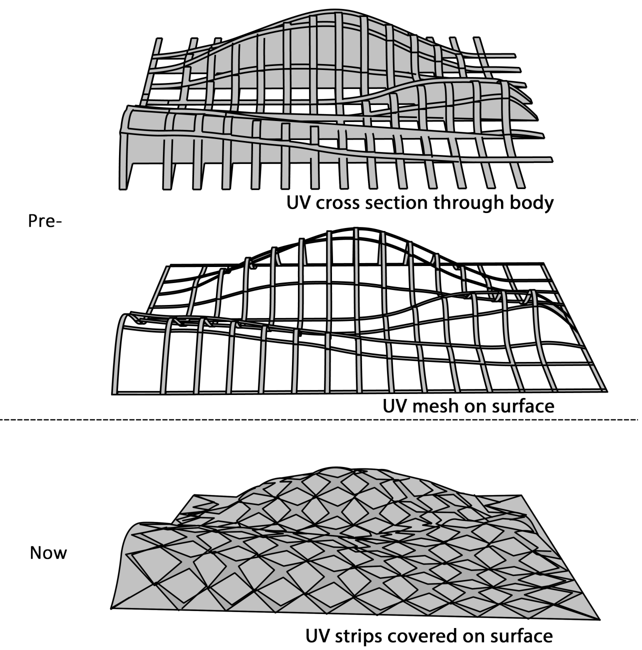

Figure 1: comparison of three fabrication

- Introducing a novel fabrication approach that 3D objects can be created with the surface texture for the HCI community.
- Integrating technologies of mesh modelling, patter mapping, and parameterization in our fabrication system to build multivariate interfaces.
- Demonstrating the abilities that recover complex curved surface and convey information through three application cases.

Related work

Surface textures, as the shape of 3Dmodel, can served as the interactive interface. In the field of HCI research,

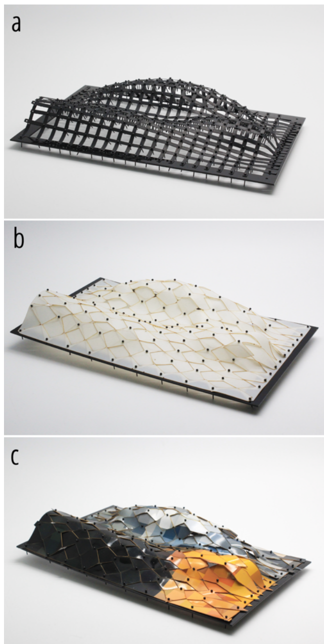

Figure 2: 2.5D surface produced by mesh structure (a) and infoTexture (b, c)

there is some previous research related to texture patterns on the surface of 3D objects as well as the interaction with textures. J Ou et al. have built a software platform to allow users to design and fabricate customized hair-like textures with high-resolution 3D printer and apply the textures to designing everyday interactive objects [6]. M Foskey et al. presented ArtNova that allows user to design and paint texture patterns on a 3D form before 3D printing the model as users can get real-time visual and haptic feedback [2]. The Dandelion Diptych has employed a dandelion-shaped electrocircuit to explore a digital painting system with LEDs controlled by code [8]. However, works in the surface texture fabrication by the commonly used prototyping technique are relatively few while our infoTexture can provide more extensive texture types to support prototyping fabrication.

At present, 3D printing is the most widely used technique to establish objects through surfaces, such as WirePrint displayed how to print the textures of mesh structure through 3D printing to promote fabrication efficiency [5]. While On-The-Fly Print has realized the function of correcting in real time which based on the grid printing to enhance the interactive function of fabrication process [7]. In addition, there are some design methods that realize 3D solid modeling by utilizing material properties to support manual construction of grid surface, such as Wire mesh design, a computer-aided design and fabrication system with mental mesh surface [3]; as Figure 2 (a) shows, CompuWoven [9] is also a kind of approach that produce 3D models by computer-aided fast and manual weaving with flexible materials. And our work (Figure 2 b, c) realized the coverage of surface textures based on the grid construction of 3D objects, which further expand the application space of the prototyping fabrication approach.

System Description

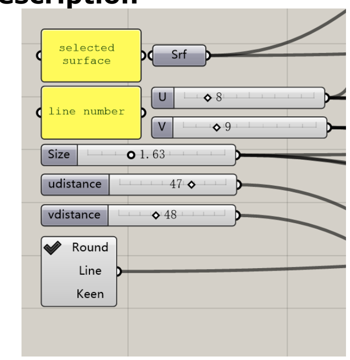

Figure 3: infoTexture system toolsets

Our system is set up on top of an algorithmic modeling platform, Rhino with Grasshopper [4], which enables both graphic programming and a visual user interface. To offer the users the clearest instruction, our system exposes merely the necessary parameters to the users. As Figure 3 shows, the system has the basic toolsets (e.g. amount of warp or weft, size, texture type) to handle the 3D models, namely, customize the geometry of the unit piece. As we change the properties of pieces and arrays, we can obtain different texture expressions; and the result can be previewed in real time.

In general, we divide them into three categories:

Programming shape of texture

Our system can provide the method to generate pieces in various kinds of shapes, such as arcuate piece and rhombic piece, which can produce different shapes and semantics product texture after assembling. In our

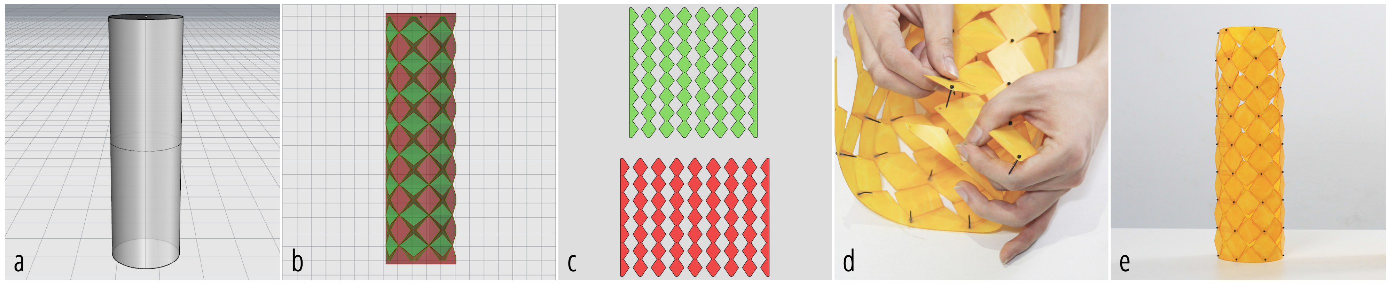

Figure 4: infoTexture workflow

system the extent of surface texture presented on 3D objects is according the pierced state of planar pieces to adjust.

Mapping patterns on texture

InfoTexture also allows complex mapping patterns on surface texture besides the shape and texture expression without patterns. To start, the pattern information on the surface of 3D objects is mapped onto the surface of the materials which need to be cut by laser-cutting machine. Then, the surface texture of 3D forms is covered with pattern information after users weaving the cutting pieces which filled with mapping patterns into 3D objects. In this process, our system enriches the expression of product groups, which is also easy to understand from the texture surface.

Texture as a DIY interface

Compared to the structures without any patterns and information, the texture on 3D models provide users a DIY interface which allows them to interact with the surface as they want to, such as: paint, fold and cut. In essence, our approach can achieve the personalized effects that encourage the interaction in the process of assembly and enrich the diversity of conveying information.

Workflow

We need roughly five steps to complete the whole modeling and fabrication process (Figure 4). First our system decomposes the digital 3D models (a) into two lists of basic texture pieces (b), of which the properties follow the changes of the parameters. Then the basic texture pieces are tiled into the 2D plane (c) as the guide path for laser cut. We assembled fabricated materials (d) into the actual 3D forms (e) after generating assembly materials from 2D plane which are segmented by the laser-cutting machine.

Applications

To show the capability of the infoTexture, we present three application examples on different textures.

Shape of texture: various lampshades

As the 3D object texture is generated by repeating UV pieces in infoTexture, it can be customized the shape by modulation of the parameter tools on edges of these pieces. Figure 5 shows two lampshades with different textures on light transmission performance due to its

Figure 5: Lampshades (a) right angle pieces (b) rounded-corner pieces

right angle or rounded-corner pieces. In addition, the rounded-corner lampshade gives a flower-like semantics due to the round shape, while the another one gives more regular expression due to its cylinder-shaped and full covered surface.

Pattern on texture: new stereograph of Van Gogh's Sunflowers

Pattern is the most intuitive information to the texture surface, and with the pattern mapping technique, what we can ensure is the 2D pattern would be accurately mapped into the 3D model, then segmented and flattened to the 2D path. Figure 6 shows the recreation of Van Gogh's *Sunflowers* painting by infoTexture to build a new stereograph. To realize the idea, we firstly built the 3D model and, print the corresponding patterns texture on handy materials like paper, cutting the output path by a laser cutter and assembling by hands before achieving the final stereo-sunflowers. It took about two hours in the fabrication process by the team work of three members. We applied this method to rebuild the world-famous painting to obtain new application space, such as creating new artist work, developing new handwork method, or exploring a stereo-puzzle interactive way.

Figure 6: New stereograph of Vincent van Gogh's Sunflowers

DIY interface: individual pen holder

Blank surface is a natural DIY interface to encourage people to interact and create. We first fabricated a cylinder with no texture patterns. Then we invited a designer to test the infoTexture and require her to make one personalized item. She learned the system quickly to build a cylinder pen holder covered with full texture. After the fabrication process, she thought the shape was too simple and the blank texture looked boring, so she picked a mark pen and a scissors to paint and cut, and finally transformed the cylinder to a cartoon pen holder (Figure 7).

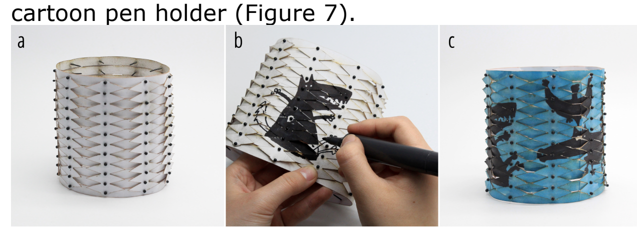

Figure 7: The DIY pen holder

Conclusion and Future Work

By conducting application cases, we demonstrate the new opportunities of our rapid prototyping system as a user interface for information expression and communication.

In the future work, we will fine-tune the parametric setting with Grasshopper to further consider complex conditions (e.g., enhancing the system's flexible tools compared with our current implementation to build multiple surface texture on stereo shape; and extending available techniques to different materials for 2D and 3D object designs). We want to explore how to apply the computational approach to a more interactive fabrication process and further test the benefits and limitations of the system.

Acknowledgement

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