3D Color Contoning

Extended Abstract

Vahid Babaei
MIT CSAIL
32 Vassar Street
Cambridge, Massachusetts 02139
babaei@mit.edu

Kiril Vidimče
MIT CSAIL
32 Vassar Street
Cambridge, Massachusetts 02139
kvidimce@mit.edu

Michael Foshey
MIT CSAIL
32 Vassar Street
Cambridge, Massachusetts 02139
mfoshey@mit.edu

Alexandre Kaspar
MIT CSAIL
32 Vassar Street
Cambridge, Massachusetts 02139
akaspar@mit.edu

Piotr Didyk
Saarland University, MMCI and MPI Informatik
Campus E 1 7
Saarbrücken, Saarland 66123
pdidyk@mmci.uni-saarland.de

Wojciech Matusik
MIT CSAIL
32 Vassar Street
Cambridge, Massachusetts 02139
wojciech@mit.edu

ABSTRACT

We introduce a novel color reproduction method for 3D printing. In contrast to currently used halftoning techniques that use surface color mixing, our technique mixes colors inside the printed volume. This mitigates the variety of artifacts associated with color halftoning.

CCS CONCEPTS

• **Computing methodologies → Reflectance modeling**; *Image processing*; *Perception*; • **Hardware → Printers**; *Displays and imagers*;

KEYWORDS

Fabrication, 3D Printing, Color, Halftoning, Color reproduction

ACM Reference format:
Vahid Babaei, Kiril Vidimče, Michael Foshey, Alexandre Kaspar, Piotr Didyk, and Wojciech Matusik. 2017. 3D Color Contoning. In *Proceedings of SCF '17, Cambridge, MA, USA, June, 12-13, 2017,* 2 pages.
https://doi.org/10.1145/3083157.3092885

1 INTRODUCTION

Additive manufacturing enables the design and reproduction of intricate geometries, and fabrication of novel multi-material composites which cannot be created using existing manufacturing techniques. A novel research area enabled by additive manufacturing is the fabrication of objects with a desired appearance. There is a wide range of application: from medicine and cultural heritage protection to anti-counterfeiting and animation. For many applications, reproducing the diffuse color is sufficient to guarantee an appearance reproduction without objectionable differences.

SCF '17, June, 12-13, 2017, Cambridge, MA, USA

ACM ISBN 978-1-4503-4999-4/17/06…$15.00
https://doi.org/10.1145/3083157.3092885

2 COLOR CONTONING

Color reproduction is a mature field in 2D printing. Almost all 2D printers are restricted to depositing discrete choices of materials at any given point on the surface. Therefore, *halftoning* techniques are employed to create an illusion of continuous-tone colors. Although halftoning is a clever solution for devices with binary tone reproduction, it has some drawbacks. Most importantly, the spatial halftone patterns can introduce visual artifacts which are particularly noticeable when the printed image is viewed from a close distance.

Similarly to 2D printers, 3D printers are also "discrete" devices and share the same restrictions. Instead of adapting 2D color reproduction methods to 3D printing, we propose to utilize the inherent ability of 3D printers to layer different materials on top of each other. We propose a "contoning" technique which prints layers of color inks around a white, diffuse material [Babaei et al. 2017]. In contrast to halftoning, our technique synthesizes colors by combining the inks within the volume of the object. Hence, regardless of the viewing distance, the decomposition of the color into multiple base materials remains invisible to the eye of the observer. Contoning mimics much better traditional materials which are often built from layers, such as wood, skin, marble, etc.

3 RESULTS

We use a custom, inkjet 3D printer with UV curable inks to explore different problems and trade-offs in the design of our color reproduction workflow, such as material design, and the layering order. We show that, compared to the halftoning algorithms, our method is free of spatial artifacts and has a much more scalable color prediction (Figure 1). Furthermore, our technique can create plausible color prints at very low resolutions. On the other hand, contoning requires a larger number of color layers than halftoning. Therefore, it is more prone to dot gain. We propose a simple and effective method to counteract this effect.

4 CONCLUSIONS

Our new color reproduction system for 3D printing is simple. While we believe this to be one of its main virtues, it is largely thanks to

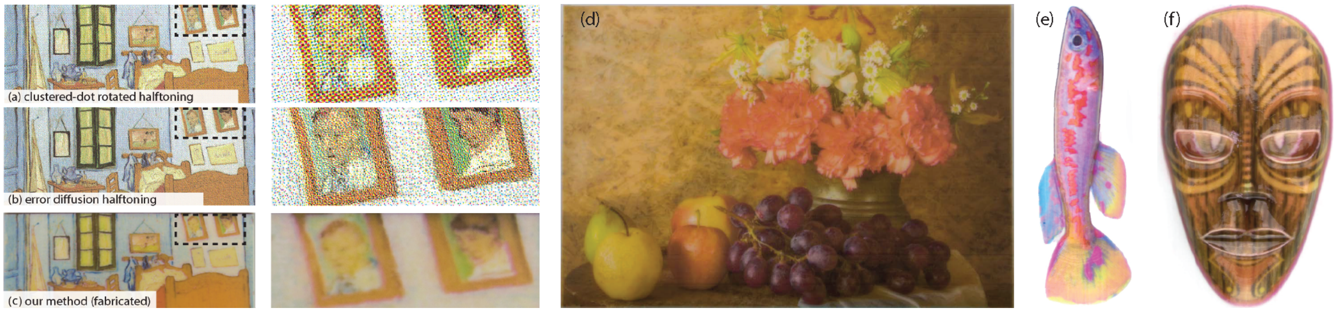

Figure 1: We introduce a novel color reproduction method for 3D printing. In contrast to halftoning techniques that create colors by spatial combination of inks on the surface, our method creates colors by superposing inks inside the printed volume. This mitigates a variety of artifacts associated with halftoning. Parts (a) and (b) of the figure show the preview of an image generated using clustered-dot rotated halftoning and error-diffusion halftoning, respectively. Part (c) shows a photograph of the 3D printed image using our technique. Parts (d), (e) and (f) present three examples fabricated with our technique on a custom, multi-material 3D printer.

eliminating the need for halftoning. 3D color contoning can pave the way for high-definition color reproduction for 2.5D and 3D printers.

REFERENCES

Vahid Babaei, Kiril Vidimče, Mike Foshey, Alexandre Kaspar, Piotr Didyk, and Wojciech Matusik. 2017. Color contoning for 3D printing. *ACM Transactions on Graphics (TOG)* 36, 4 (2017).