Color Reproduction Framework for Inkjet FDM 3D Printers

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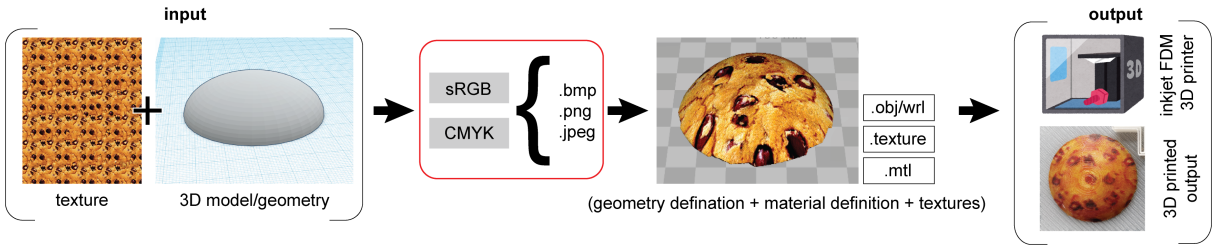

Figure 1: *The color reproduction workflow for inkjet FDM 3D printers. Our work focused on the process of formatting the image texture to the color profile before printing (red circle).*

Abstract

Recent advances in consumer-grade 3D printers have enabled the fabrication of personal artifacts in aesthetically pleasing full color. However, the printed colors are usually different from the actual user desired colors due to the mismatching of droplets when the color reproduction workflow has been changed or the color profile setup is missing. In this paper, we present a preliminary experiment to investigate color reproduction errors in consumer-grade inkjet FDM 3D printers. Our results suggest that solving the problem requires initiating the workflow to minimize color reproduction errors such as using CMYK or sRGB color profiles. We also found that the mismatched color gamut between the input's desired texture and the 3D printed output depends on different file formats, and this finding requires future investigation.

CCS Concepts

• ***Computing methodologies*** → ***Computer graphics;*** *Visibility;*

1. Introduction

Recent advances in consumer-grade 3D printers have enabled the fabrication of personal artifacts in aesthetically appealing with full color. However, the printed colors are usually different from the actual user desired colors due to either the mismatching of droplets with the input color or the color profile setting. Furthermore, surface materials affect color reproduction in the colored 3D printing process.

Recent works in color reproduction have investigated methods to correct the color profile, i.e., to enable printing the artifact in the same color as the input desired. While such previous work has contributed directly to improve inkjet solid-polymer 3D printing [ESZ*17, RSB*21], the color profile used is not applicable to an inkjet FDM 3D printer, in which the projected color drops directly on the 3D printed filament. In this work, we present a preliminary investigation into color reproduction in inkjet FDM 3D printers (Fig. 1)). This study aims to identify color reproduction issues found in inkjet FDM 3D printers and the potential solution to refine colors based on the user input.

2. Color Reproduction for Inkjet FDM 3D Printers

Color reproduction for inkjet FDM 3D printers is similar to the color process for 2D printers, as it begins with the user creating or selecting the texture they want, and then this selection is applied to a 3D object (Fig. 1). The printing software then slices the 3D object with texture into a layer and maps the colored parts into color channels, e.g., sRGB color space. However, it is unknown whether color space should be used to create textures that allow reproducing the same color as the user's desired input. We conducted the following preliminary experiment to identify the closed color space that

DOI: 10.2312/egp.20211027

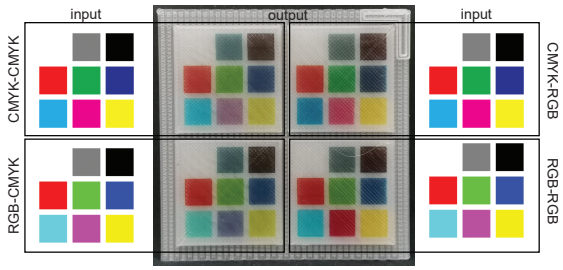

Figure 2: *The result of different input preparation processes; input with CMYK and output with CMYK (top-left), input with CMYK and output with sRGB (top-right), input with sRGB and output with CMYK (bottom-left), and input and output with sRGB (bottom-right).*

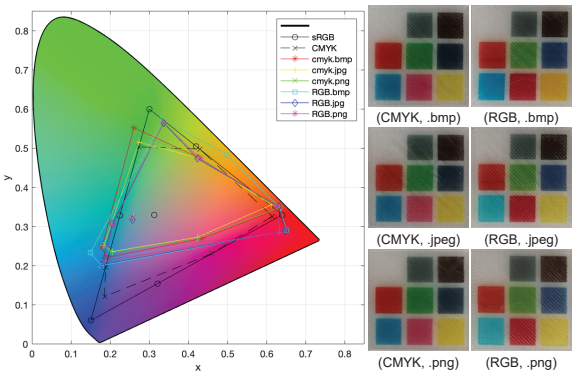

Figure 3: *The resulting color gamut for each workflow compared with the traditional sRGB workflow.*

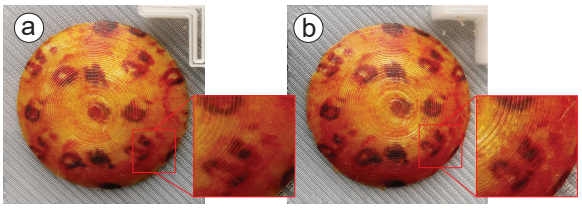

Figure 4: *3D printed object using a texture process with (a) the proposed workflow (CMYK-sRGB) and (b) the standard workflow (sRGB-sRGB).*

should be used as the suitable input color profile for inkjet FDM 3D printers.

2.1. Preliminary Experiment

We conducted an experiment to print the 3D artifact with a user desired color texture. We started by creating a texture from a custom software to obtain an original color profile. Then, we processed that image using sRGB color space for a reference r and CMYK color space for a comparison c using three different file formats; bmp (r_{bmp} and c_{bmp}), png (r_{png} and c_{png}), and jpeg (r_{jpg} and c_{jpg}), respectively. We mapped the image as a surface texture of a 3D object and directly processed it through the inkjet FDM 3D printer (XYZ printing da Vinci Color Mini 3D Printer) software, which sliced and processed the ink droplet according to the input file using sRGB color space.

Once the 3D objects were printed, we observed the printed color information through a spectrophotometer (Spectrolino CH-8105) with the following conditions; D65, polarized filter, reflection at 2 degrees of observer, and under the white base with black backing. We compared the color profile between the original digital file and the printed one (condition k_1), between each printed output (condition k_2), and with the one in which we customized the slicer with a CMYK color space instead of sRGB (condition k_3). In total, our setup included the following; 3 conditions $\times$ 2 color profiles $\times$ 3 file formats = 18 trials.

2.2. Results

For conditions k_1 and k_2, we found that CMYK works the best and that the 3D printed results matched closely to the input texture. While r is the traditional workflow for inkjet FDM 3D printers, we found that c produced a more accurate color output. As shown in Fig. 3, the color gamuts of the two workflows have distinct differences. In particular, the c_{bmp} has a wider range compared to those of c_{jpg}, c_{png}, r_{jpg}, r_{png}, and r_{bmp}, respectively.

For condition k_3, we found that the CMYK-sRGB workflow reproduced the color better than the one with CMYK-CMYK and sRGB-CMYK (Fig. 2). Hence, we found that it is better to prepare the image texture/color texture for printing the 3D object with a CMYK color space rather than the traditional 3D color printing process, which usually starts with an sRGB color profile. Furthermore, it is also recommended to use the c_{bmp} over the other file formats as it is the most uncompressed file type.

We also verified our proposed workflow by creating a sample 3D textured object, i.e., cookie, comparing our recommended workflow with the traditional 3D color printing workflow. The 3D object printed with our workflow provided higher quality color reproduction (Fig. 4, left) compared to the one with the standard workflow (Fig. 4, right).

3. Conclusions

We presented a preliminary study to investigate the color reproduction error in inkjet FDM 3D printers. Our results suggested that solving the problem requires initiating workflow that allows for minimizing errors in color reproduction using the CMYK color profile. We plan to further investigate the characteristics of color reproduction in inkjet FDM 3D printers such as the effects of subsurface and color optimization from droplets.

References

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