Pixel Sweeping Technology enabling 3D Printing of Large-Scale Objects with Delicate Details

Ran He[1,*], Wentao Shi[1] and Yaling Liu[1,*]

[1]Lehigh University, 7 Asa Drive Room 327, Bethlehem, PA 18015, USA, rah212@lehigh.edu

ABSTRACT

Stereolithography based 3D printing is widely used in both industrial and consumer market due to the high precision and printing speed. On the other hand, customers and industry manufacturers desire a high performance technique that can enable the direct fabrication of integrated large-scale objects with delicate details in a fast speed. We have developed a pixel sweeping 3D printing technique that allows the UV projector continuously cures the resin when scanning over the build area to print large objects with delicate details. This scalable 3D printing technology enables the customized build volume in large-scale (can be even larger than 1 m^3), while remains the micro-scale features and smooth finish. Our 3D printing technique with the ability in large-scale fabrication and volume production is expected to provide ideal solutions in medical, dental, jewelry, automotive, and aerospace industries.

Keywords: 3D Printing, Large-Scale, Lithography, micro resolution

1 INTRODUCTION

With the recent explosion of the 3D printing market, fast and low-cost prototyping has been made possible[1]. However, consumers desire improvements to the performance metrics of these machine, mainly printing speed, resolution, and size and material choice. While the most common printing methods, Fused Deposition Molding (FDM) and Stereolithography Apparatus (SLA), work well for rapid prototyping, they must be improved to keep up with market demand. Advancements to the technology extend the reach of potential applications to include medical, dental, jewelry, and production-level uses.

Improving upon the developments in SLA printing, using digital light processing (DLP) based on Digital Micro-mirror Device (DMD) enables a faster approach in fabrications[2]. Lu et al. developed the DLP based 3D printing technique to polymerize the entire layer at once[3]. As a result, the DLP method yields faster print times and higher print resolution. Based off of the DLP developments, DeSimone's group developed the technique of Continuous Liquid Interface Production (CLIP)[4]. The machine projects a continuous sequence of UV images through an oxygen permeable membrane which inhibits polymerization at the border. The technology increases printing speed due to the continuous movement. Despite these improvements, these machines are still limited in build area size. For larger objects, users would have to print parts in pieces and splice them together, requiring additional labor and lowering resolution.

To increase the build area for large-scale printing, Lee et al. produced a DLP-based printer with motors for two-dimensional (X and Y) axial movement[5]. The printer divides the layer image into overlapping sub-region images. In this system, the projector moves to the area, exposes the resin underneath to the sub-region image, and then sequentially moves to the next region. The technology improves greatly in build area size and is also scalable, as the algorithm is capable of processing larger parts than the current printer can handle. However, this technique still lacks in speed and quality. In particular, the algorithm requires the projector to expose each sub-region individually. Furthermore, larger objects require more sub-regions, which means more wasted time as the system is scaled up. Also, division of images into sub-regions inherently creates flaws in the resolution. The borders of each sub-region must be stitched together.

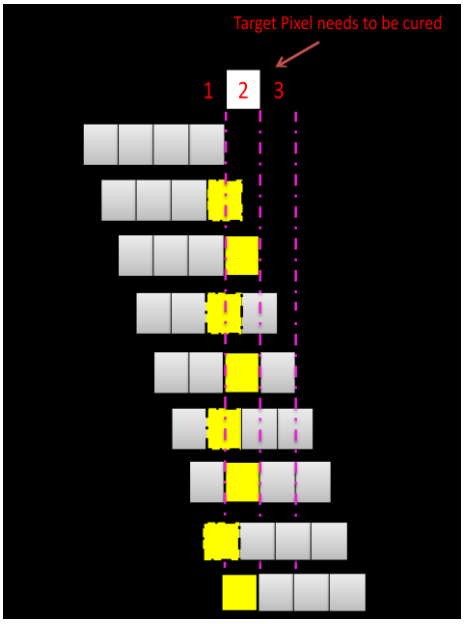

Figure 1: Illustration of pixel sweeping technology

We have developed a pixel sweeping technology that allows for smoother and faster large-scale printing. The

projector and animated images move in sync such that a still image appears on the build plate. As a result the algorithm greatly reduces the amount of stitching needed, improving print resolution. The algorithm more efficiently utilizes time during scanning projection, requiring fewer pauses than previous technology. The printer and algorithm is scalable technology, where the printing size and resolution can be improved for even larger prints with even higher resolution. We designed our printer and algorithm for industry professionals, research scientists, and even DIY users---anyone who needs large parts with fine resolution.

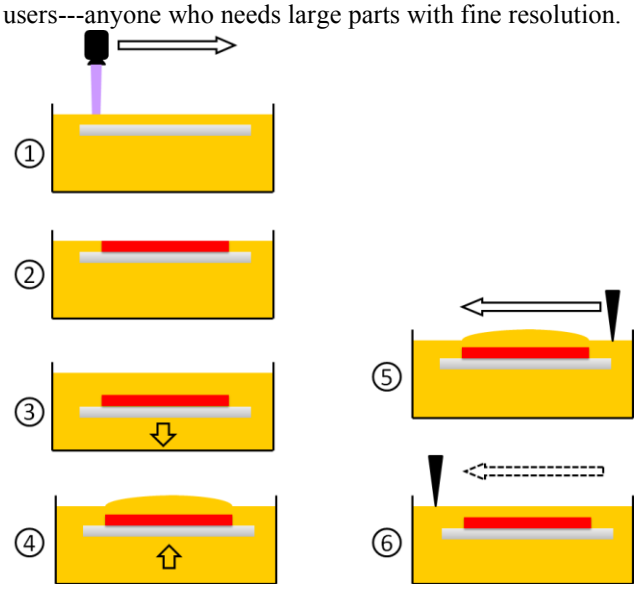

Figure 2: Printing Process

2 RESULTS AND DISCUSSION

DLP based 3D printing methods require two key elements: a build platform which holds the printed objects, and a projecting system that utilizes the DMD to reflect light and expose patterned images. The DMD used in this research has 1200×800 micro-mirrors, which individually rotate to reflect the UV light and polymerize the photocurable resin. The pixels projected on the resin, which correspond to those individual mirrors, determine the theoretical resolution of the projected pattern. During the light exposure process, traditional DLP printing methods fix the position of both the projecting systems and the build platform to enable steady polymerization in target area. The technology presented in this paper utilizes a pixel sweeping technology that allows the projecting device to move continuously and project animated patterns when printing objects. The area exposed to UV light in the printing layer gradually cures during the scanning of the projecting device. When the photocurable resin is exposed to the UV light in the oxygen-rich environment of the air, a thin layer of uncured resin remains on the top of the cured surface due to the oxygen inhibiting effect of UV induced polymerization. To cure the photocurable resin with a preset thickness, a certain exposure time of UV light is required in a environment of fixed light intensity and oxygen concentration. In this printing technology, the target curing area is exposed continuously and repeatedly to ensure the sufficient and proper curing thickness.

The key aspect of the technology is the dynamic sweeping process of pixels. A micro-mirror is activated when the reflected UV light enters the target printing area. Traditional DLP printing methods are static—controlling each pixel by activating the single corresponding micro-mirror on the DMD once per layer. Our pixel sweeping process, however, controls each pixel by sequentially activating micro-mirrors as the projecting system scans along a pathway (Figure 1).

To ensure high resolution of the printed part, there must be a smooth, even layer of resin on the top surface. Without this even layer, the printed part is subject to surface roughness, drooping layers, and curling of the part (especially in the beginning layers). These flaws are both aesthetically and functionally unacceptable. Since the newly exposed layer bonds to the previous layer below it, the problem with the approach of submerging in and reemerging the part from the resin is that surface tension creates an uneven layer on the surface. More viscous resins create even more of an issue. To combat this, the printer includes a wiper that moves across the build plate after it reemerges to the surface (Figure 2). Using this pixel sweeping technology, we managed to print parts with a wide range in size. Printed samples has been illustrated in Figure 3.

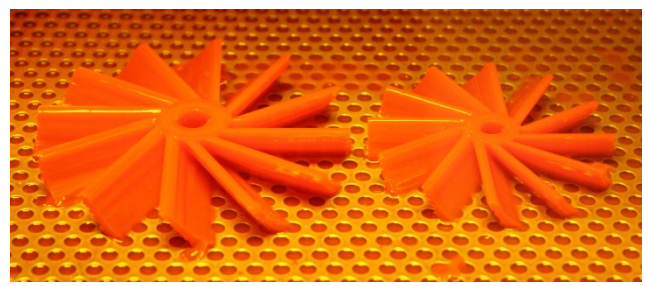

Figure 3: Printed samples

3 CONSLUSION

We used a pixel sweeping technology that enables the printing of large objects with delicate. This scalable 3D printing technology enables the customized build volume in large-scale (can be even larger than 1 m3), while remains the micro-scale features and smooth finish. With the applying of self-regulated wiping system, our 3D printing technique is compatible with various materials, leading to the direct manufacturing of final parts from functional photocurable materials. Our 3D printing technique with the ability in large-scale fabrication and volume production is expected to provide ideal solutions in medical, dental, jewelry, automotive, and aerospace industries.

REFERENCES

[1]C. Groth, N. D. Kravitz, P. E. Jones, J. W. Graham, and W. R. Redmond, "Three-dimensional printing technology.," *J. Clin. Orthod.*, vol. 48, no. 8, pp. 475–85, 2014.

[2]R. He, D. Yunus, C. Uhl, W. Shi, S. Sohrabi, and Y. Liu, "Fabrication of circular microfluidic channels through grayscale dual-projection lithography," *Microfluid. Nanofluidics*, vol. 21, no. 1, p. 13, 2017.

[3]Y. Lu, G. Mapili, G. Suhali, S. Chen, and K. Roy, "A digital micro-mirror device-based system for the microfabrication of complex, spatially patterned tissue engineering scaffolds," *J. Biomed. Mater. Res. - Part A*, vol. 77, no. 2, pp. 396–405, 2006.

[4]J. R. Tumbleston, D. Shirvanyants, N. Ermoshkin, R. Janusziewicz, A. R. Johnson, D. Kelly, K. Chen, R. Pinschmidt, J. P. Rolland, A. Ermoshkin, E. T. Samulski, and J. M. DeSimone, "Continuous liquid interface production of 3D objects," *Science (80-.).*, vol. 347, no. 6228, p. 1349 LP – 1352, Mar. 2015.

[5]M. P. Lee, G. J. T. Cooper, T. Hinkley, G. M. Gibson, M. J. Padgett, and L. Cronin, "Development of a 3D printer using scanning projection stereolithography.," *Sci. Rep.*, vol. 5, p. 9875, 2015.