Sacriface: A Simple and Versatile Support Structure for 3D Printing

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ABSTRACT

Digital fabrication serves as a potent instrument for facilitating interaction between the real and digital realms. However, the process is becoming increasingly complex amidst its development. We present Sacriface, a simple and versatile support structure for 3D printing which allows us to obtain further efficiency and flexibility in 3D printing. We simplified the strategy of expanding support structures taking advantage of a stable, growing overhang that gradually recovers its original shape as printing thickness increases. Sacriface is effortlessly designed and printable using an unmodified 3D printer, which enhances user customization.

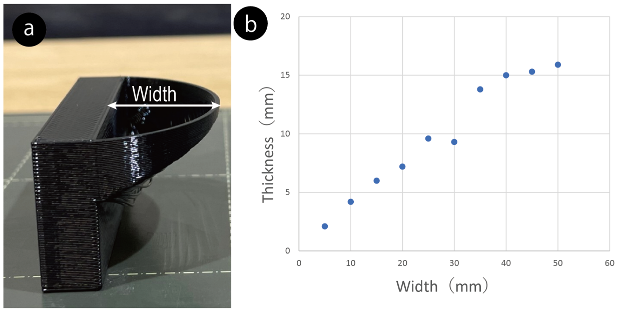

Figure 1: (a) The overhang recovering its semicircular shape as printing thickness increases. (b) The relationship between the width and the required thickness.

CCS CONCEPTS

• **Human-centered computing** → *Human computer interaction (HCI).*

KEYWORDS

3D Printing, Support Structures, Personal Fabrication, Failure

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1 INTRODUCTION

Fused filament fabrication (FFF) is a powerful tool for realizing 3D digital designs into physical objects. On the other hand, the process of stacking filaments layer by layer has a major drawback in that it requires long print time and extra usage of support materials. In order to facilitate real-world interaction, numerous studies have explored methods to reduce print time, such as printing the outlines[6], reducing the size of printed objects [5, 7], and incorporating additional processes [1, 8].

There are two main types of support structures [3]: linear and branching. Linear support structures are reliable because they are continuously layered vertically, but branching support structures offer the potential for further reduction in print time and filament consumption [9]. Bridge structures also develop from smaller ones, and increase the reliability of branching support structures [2]. However, computational cost remains a persistent challenge.

We simplified the strategy of multiplying points that can support the upper layers, which is a characteristic making branching support structures efficient. The high calculation cost of branching support structures is caused by their strict constraints and many parameters such as branching angle, length of the supporting strut, and structural stability [4]. We focused on printing without support structures. In general, overhang paths deform due to gravity-induced sagging and pulling caused by the movement of the nozzle. However, we confirmed that some overhangs are printable without support structures just by repetition. In Figure 1 (a), The nozzle moves on a semicircular path of constant radius, but the filament comes untethered along the path, resulting in a straight, hanging cord that sticks again at the end of the semicircle. The untethered hanging portion is reduced at each path, finally forming a full solid semicircle. Taking advantage of this "recovery", we can multiply supporting points starting with two endpoints by widening the bridging structures [2] and repeating the printing until the shape is recovered. We call this new type of support structure "Sacriface".

2 DESIGN METHOD

We design Sacriface using shapes such as arcs and rectangles because deformation becomes more severe as the complexity of the path increases. We investigated the rate of recovery of the circular path, that is the relationship between the width and the required

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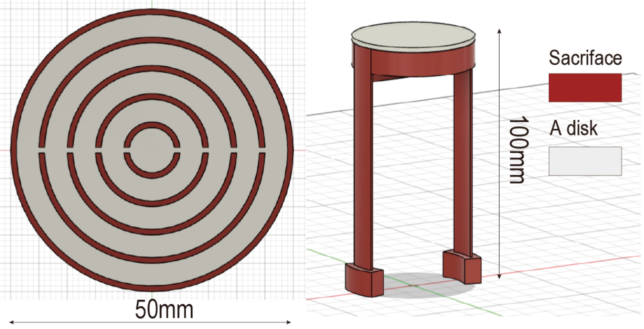

Figure 2: Sacriface supports a disk with a diameter of 50mm situated at a height of 100mm. Print time: (Sacriface) 59m, (Grid) 2h4m, (Snug) 1h38m, (Branching) 1h36m. The other three support structures were automatically generated in Prusa Slicer. Grid and Snug are two kinds of linear support structures.

thickness shown in Figure 1 (b). Small arcs are recovered immediately and ultimately, it is possible to expand the range of supports up to a distance equivalent to that of the endpoints. In the CAD software, the user designs a half-cylinder under the shape that needs to be supported. The supported part must lie atop the cylinder. The thickness of the cylinder can be adjusted according to Figure 1 (b).

3 CHARACTERISTICS

In addition to its simplicity in design, Sacriface serves as an efficient support structure. We compared the print time of Sacriface with existing support structures. In the shape indicated in Figure 2, Sacriface demonstrated the fastest print time. High efficiency can be explained by its quickly expanding width. In spite of sacrifices made during the recovery process, the enforced 90-degree angle overhangs quickly expand support structures. Planar expansion of Sacriface makes it possible to support multiple locations with a single path, suggesting a potential of more efficiency, unlike individually generalized branching structures. Furthermore, Sacriface is space-efficient. The compact height suggests the possibility of omitting the lower part of the linear support structures using Sacriface. The thickness of Sacriface does not depend on the height of the printed object. Therefore, it contributes to reducing printing time and filament usage, especially for objects with greater height.

4 EXAMPLES OF APPLICATIONS

Sacriface can be personally designed to enhance printing efficiency. The simplest application is indicated in Figure 3 (a). In 3D printing, Numerous overhangs get printable by adding a few supporting points. When using Sacriface, the expected printing time was reduced compared to the automatically generated support structures in the object in Figure 3 (a).

In addition, Sacriface can be combined with existing support structures and applied into complex shapes keeping ease of design owing to its simple shape and plane structure. In Figure 3 (b), an inserted plane surface connects Sacriface with existing support structures. Despite the additional surface, Sacriface still contributes to the efficiency of support.

Figure 3: Examples of applications of Sacrifacace: (a) bridge, (b) plane surface, (c) hammock.

Furthermore, taking advantage of planar expansion, we can utilize a printable area with more flexibility. As shown in Figure 3 (c), Sacriface expands the utilization of the vertical dimension, allowing for the mass production of small [1, 5, 7, 8] objects at once. Using wider surfaces reduces the number of pillars.

5 CONCLUSION AND FUTURE WORK

In this paper, we presented a novel support structure for 3D printing which is simple and easily manageable by users. We emphasize allowing for partial sagging and deformation sometimes leads to enhancing efficiency. The unique strategy of Sacriface mitigates the constraints in 3D printing. Further development involves evaluating the process of deformed overhangs recovering their original shapes and streamlining the structure.

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