FusePrint: A DIY 2.5D Printing Technique for Good-fit Fabrication with Daily Objects

Kening Zhu
School of Creative Media, City University of Hong Kong
keninzhu@cityu.edu.hk

Shengdong Zhao
NUS-HCI Lab, School of Computing, National University of Singapore
zhaosd@comp.nus.edu.sg

Alexandru Dancu
Augmented Human Lab, Singapore University of Technology and Design
alex@ahlab.org

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Abstract
FusePrint is a Stereolithography-based 2.5D rapid prototyping technique that allows high-precision fabrication without high-end modeling tools, enabling the mixing of everyday physical artifacts and liquid conductive gels with photo-reactive resin during the printing process, facilitating the creation of 2.5D objects that perfectly fit the existing objects. Based on our polynomial model on 2.5D resin printing, we developed the design interface of FusePrint, which allows users to design the printed shapes using physical objects as references, generates projection patterns, and notifies users when to place the objects in the resin during the printing process. FusePrint could be useful for a wide range of application domains including: mechanical fabrication, wearable accessory, toys, interactive systems, etc.

Author Keywords
DIY, 3D Printing, 2.5D Printing, SLA, Daily Objects.

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

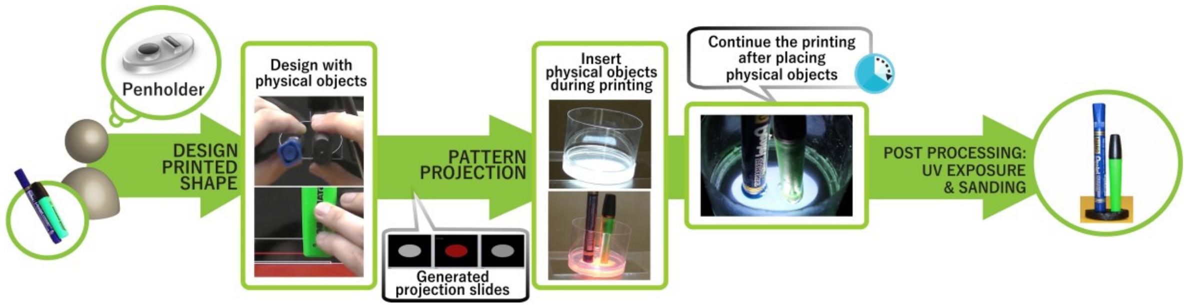


Figure 1: FusePrint fabrication process. User wants to create a penholder; its shape is designed with the reference of physical objects, and bprojected through the bottom of the container holding the resin and physical objects (pens). The projected shape solidifies, resulting in being perfectly matched to the objects.

Introduction

While 3D printing has become increasingly precise in the past decade, using it to create objects that can tightly fit with real-world artifacts can still be challenging [1] despite the availability of tools to create 3D models from existing objects. This is because physical objects can have complex geometric structures (e.g., an internal screw thread). While fitting objects within a simpler structure, such as a cube, is theoretically easy, in practice, daily wear and tear may transform parts or the whole of that simple object into a more complex shape/texture, increasing the difficulty of modeling. High-end 3D scanning devices can achieve greater precision, but they are usually costly and less accessible for hobbyists. Even if a perfect 3D model can be created, much of the printing process in current low-cost 3D printers may introduce additional errors due to the difficulty in calibration(e.g., it can be difficult to 3D-print the details of an internal screw thread in an object to tightly fit the existing screws). These factors could result in a long chain of trial-and-error attempts with current 3D printers to produce objects that fit existing artifacts well. One solution is to leverage existing artifacts as a mold so that the printing material in contact with the artifact can naturally fit to its shape and texture. However, the current 3D-printing processes do not support the insertion of physical objects in the printing process.

In this paper, we demonstrate our first effort to enable the capability of inserting existing artifacts in the fabrication process with FusePrint, a DIY SLA-based 2.5D printing technique that allows for the mixture of everyday objects as well as liquid with the photo-reactive resin during the printing process, making it much easier to create 2.5D objects that tightly fit with the existing objects. Using FusePrint, one can simply place daily objects, like an external screw thread or a cup, into the photo-reactive resin during the printing process to print an internal thread or a cup holder that perfectly matches the shape of the inserted objects. In addition, by mixing liquid conductive gel with the resin, one can print customized touch-sensitive objects that can detect multi-touch points as well as gestures.

Related Work

Researchers have long discovered the advantages of mixing existing artifacts with 3D created objects and have developed various tools to facilitate this process. For example, MixFab is a mixed-reality environment for personal fabrication, which allows users to create models by placing physical objects in the workspace [1]. Printed Optics [2] adopted the shape-deposition-based process that still requires the detailed 3D models of embedded components. Chen et al. [3] proposed Encore, an FDM-based 3D printing technique to augment everyday objects in three ways: printed-over, affixed, and interlocked. ReForm [4] leveraged the usage of malleable clay to allow users to create physical 3D models in a bi-directional way, supporting the usage of markers and physical objects as the annotation of modeling. Teibrich et al. [5] presented a 3D-printing technique that supports direct modifications (i.e. addition and subtraction) on the already-printed objects using 3D scanning, to reduce the waste of the material because of the failures in fabrication.

In all mentioned work above, researchers have mainly focused on using physical objects in the modeling process, requiring 3D scanning. As previously mentioned, the modeling process itself can be tedious by requiring extra measuring tools, and errors could still occur during the scanning and the manufacturing process due to the non-perfect hardware implementation of FDM 3D printers.

FusePrint Setup

With FusePrint, we aimed to create a DIY process that could create objects to fit existing objects. We developed a DIY setup (Fig. 2) with four main components: a tablet for shape designing, a light source using an existing Optoma DLP projector (model = EH1060; brightness value = 0; contrast value = 0), a resin container, and a computer. The projector is mounted in the acrylic case, directing upward to the container filled with photo-reactive resin.

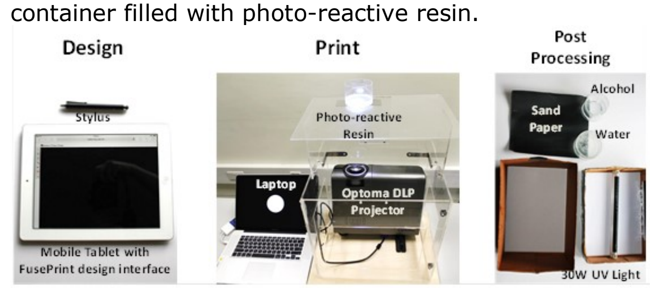
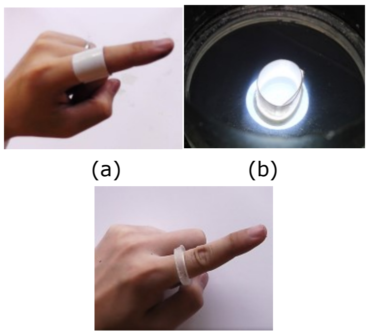


Figure 2: FusePrint Setup

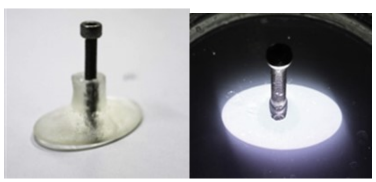
The base of the resin was made of flexible silicon, to facilitate easy-removal of the printed shapes. To achieve maximum illumination, the distance between the projector and the resin container is set to be the minimum projection distance of the projector model (22 cm in our setup). The computer is connected to the projector to control the projected images to create objects layer by layer.

To print a 2.5D object, one can shine a sequence of slides through a DLP projector to the appropriate region of the resin to cure the resin layer by layer. The overall process of printing a 2.5D object using FusePrint consists of the following steps (Fig 1): A user first needs to specify the shape of the printed object and its dimension in our customized modeling software which contains a web-based sketch interface allowing users to design the 2.5D patterns on mobile tablets (Fig 2 - Design) and a plug-in for Microsoft PowerPoint to generate projection patterns based on the design of 2.5D shapes; the system then translates the model into a sequence of images in which each image is a cross-section of a 2.5D model representing a layer of that object needing to be printed. According to the height of



(a) (b) (c)

Figure 3: (a) user made a model of the finger using a plastic wrapper (b) the plastic wrapper is placed in the resin during printing (c) the printed ring fits nicely to the finger



(a) (b)

Figure 4: Print a screw thread (a) a physical screw is placed in the resin to create the internal structure for a thread (b) the screw can tightly fit into the thread

the layer, the image is set with different light intensity values. Each image will be shined into the resin for a pre-calculated duration to ensure the printed object has the desirable shape and height.

Once the printing process is complete, there are further steps to follow to post-process the printed result. The post-processing stage (Fig 2 - Post Processing) contains a washing container, UV light box, and sand paper. Similar to post-processing in SLA 3D printing, the user gently peels the model off the container base, washes off the remaining liquid resin on the model surface, applies UV exposure by putting the printed part in the box with a 30W UV light tube for 3 minutes, and finally sands the surface of the model to achieve the best surface result.

Usage Scenario

Depending on various needs, one can place the physical object at different stages of the printing process to create different effects. When the physical object is placed at the beginning of the printing process, it will result in a hole fitting the object's contour in the final printed product. For example, one could create a mold of his/her finger with paper/plastics/clay (which are highly accessible) and place the mold in the resin, creating a well-fitting ring (Fig 3).

Another application of FusePrint is the ability for users to place screws in the liquid resin (Fig 4a), so the resin can be cured around the screw, and create internal threads that tightly fit the particular type of screws without measuring and modeling (Fig 4b). Existing parts of the toy (hand and body) can also be placed in the resin (Fig 5a), so the printed new parts could fit into the slots in the original parts (Fig 5b and c). As the two toys are manufactured from the same company with the same standard, the new parts could be swapped to create new combinations (Fig 5d).

(a) (b) (c) (d)

Figure 5: Printing new parts for toys.

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