MiragePrinter:
Interactive Fabrication on a 3D Printer with a Mid-air Display

Junichi Yamaoka
Keio University
yamajun@sfc.keio.ac.jp

Yasuaki Kakehi
Keio University
ykakehi@sfc.keio.ac.jp

1. Introduction

The rapid proliferation of digital fabrication machines has resulted in creating an environment that enables more people to make various creations. From a viewpoint of Human Computer Interaction, it is often pointed out that interfaces bridging between works in the digital environment and the physical environment are necessary to support design for personal fabrication [WILLIS 2011] [WEICHEL 2014].

To fill the gap on the 3D print fabrication, we propose a new type of fabrication machine called ``MiragePrinter'' (Figure.1) that connects the users' digital works and physical works seamlessly. More concretely, we make three contributions.

Firstly, we propose a printer hardware, which can show floating images on a 3D printer stage. With this machine, users can simultaneously view optical images of their models and their physical manifestations in identical positions.

Secondly, we have developed software and interfaces, so that users can control the displayed images and the printer actuations simultaneously. Basically the user can design models using existing CAD software overlapped on the 3D printer's stage in real scale. In addition to this, the user can manipulate floating images through embodied interactions using head movements or rotating the stage.

Thirdly, we propose several interactive functions on this machine for connecting the modeling process and the materializing process seamlessly. Users can design digital models by referring to the parameters of the existing physical objects placed on the stage. They can also add additional parts of the existing objects themselves.

2. System Design of MiragePrinter

Our MiragePrinter consists of a 3D printer (Solidoodle 2nd Generation), a mid-air display with real imaging optics (ASUKANET AI Plate, 360mm square). We utilized the mid-air imaging display to superimpose images on physical objects. The image optics are fixed at 45 degrees to the printing table, and a display (ProLite X2377HDS: size is 286.4 x 509.2 mm and resolution is 1920 x 1080 pixels) is placed below the optical plate. By using these optics, the system can show floating images without interfering the printing mechanism and users' activities such as removing parts of the stage for all of the equipment can be installed backside of the stage. In the current implementation, the distance from the printed object on the stage to the plate was 300 mm, and the distance from the plate to the display was also 300 mm as shown in Figure 2. As shown in Figure 3, the display operates appropriately within a -20 to 20 degree range in horizontal directions.

In our system, the software is based on Rhinoceros, which is commonly used for modeling. The displayed mid-air image

Figure 1. *MiragePrinter.*

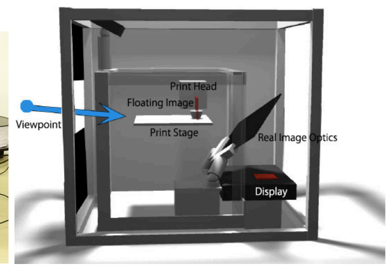

Figure 2. *System.*

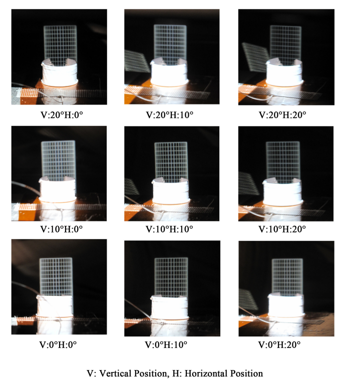

Figure 3. *Appearance of the floating image according to viewing positions.*

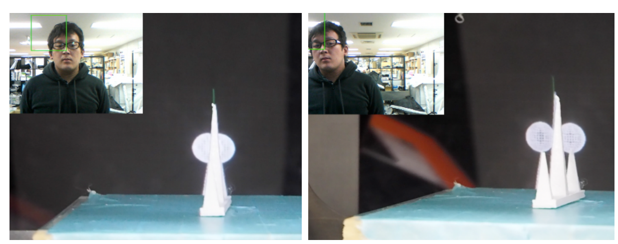

Figure 4. *Changing angles according to viewpoint.*

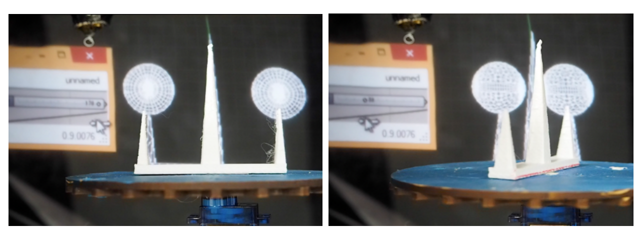

Figure 5. *Changing angles according to rotation of the stage.*

Human-centered computing~Interactive systems and tools
Keywords: Interactive Fabrication, Digital Fabrication, Mid-Air Image Display

SIGGRAPH '16 Studio, July 24-28, 2016, Anaheim, CA,
ACM 978-1-4503-4373-2/16/07.
http://dx.doi.org/10.1145/2929484.2929489

consists of a black background and white wireframe models. To coordinate the position of the mid-air floating images and printed objects, a manual calibration is needed using a grid pattern plate in advance. Although this mid-air display can show only 2D images, we utilize two methods to display pseudo stereoscopic images. One is changing the model angle by tracking the user's face. The angle of the model data can be adjusted according to the user's position so that the 3D model looks like floating on the stage (Figure 4). For realizing this function, we attached a web camera to the printer and utilized OpenCV library for the face tracking. Another method is installing a rotation stage on the 3D printer. According to the orientation of the stage, users can manipulate the rotation of the floating model (Figure 5). For this function, we designed a rotating stage with a stepping motor and a rotary encoder. The rotation data are transferred to Rhinoceros through Arduino and Grasshopper.

Users can create and modify mesh models using a standard Rhinoceros toolbox. The edited models can be exported as .stl file, and transferred to printing software (Repetier-Host). The printing software converts model data to G-code, and prints the models. Even during the printing process, the user can stop the printing temporarily and modifies models. In this case, the system erases parts of G-code that has been already printed, and resume the print using the modified G-code so that the system can keep printing on the existing printed object.

3. Functions and User Experience

We proposed several functions to support the users' design process using the MiragePrinter.

Editing 3D Objects While Printing: Here, we suppose a scenario that a user makes a smartphone stand using our system. The user can put the smart phone on the printing stage. He can test suitable angle for it physically and design the stand by referring the shape of the smartphone directly (Figure 6). As for another case, when a user creates a ring, the user creates a model of the base part by comparison with the actual size of a finger held on the stage. Then, after printing the base part, the user can design the upper ornament models, while wearing the base on her finger (Figure 7). In these ways, our system has merits such as a rough modeling, which does not require accuracy, and a modeling by comparing virtual models with other physical objects while the printing process.

Quick Shape Scanning of Existing Objects: Using our system, the user can scan and modify physical objects immediately and easily without using a high spec 3D scanner. For example, the user can get a shape data by just tracing the shape of existing objects. Figure 8 shows a scenario that the user can design an additional part for an existing toy according to the tracing shape data (Figure 8).

Direct Printing onto Existing Physical Objects: Another specific feature of this system is that it enables the user to directly add new parts to an existing physical object. For example, consider a situation where the user wants to add a new handle at the top of an existing cup (Figure 9). In the current implementation, there have been still some limitations with regard to this function: the printed surface should be flat and the adhesiveness depends on the material of the existing object. However, this function could open up a new method for fixing or customizing existing physical objects.

Figure 6. ***Editing 3D Objects While Printing*** *(Making process of a smart phone stand.*

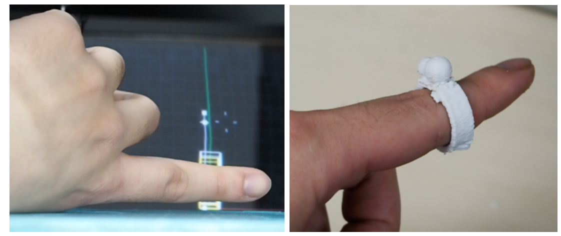

Figure 7. *Making process of a ring.*

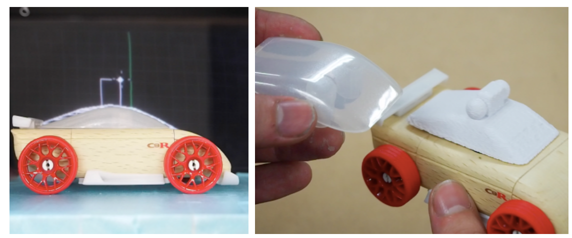

Figure 8. *Making process of a window part of a toy car.*

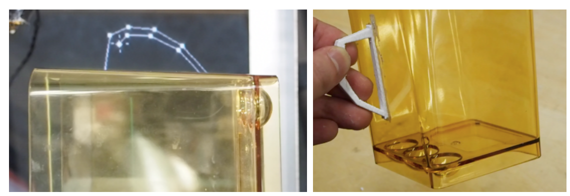

Figure 9. *Making process of a new handle of a cup.*

Participants Experiences at SIGGRAPH 2016: At the venue of SIGGRAPH 2016 Studio, we will install at least three sets of MiragePrinter so that workshop participants can experience the whole process of the creation from modeling to printing. They can use existing objects (e.g. cup, blocks) for their design. We suppose that the total experience time would be one hour (30 minutes for modeling and 30 minutes for printing). In addition, we can show a demonstration of our printer for people who don't participate the creation workshop at the venue.

4. Conclusions and Future Work

In this paper, we proposed a 3D printing machine combined with a modern floating image display. To enable a seamless creation process for users, we implemented several functions of the machine. In the future, we plan to add further functions to support creations of more complex models.

References

WILLIS, K. D., XU, C., WU, K.-J., LEVIN, G., AND GROSS,M. D. 2011. INTERACTIVE FABRICATION: NEW INTERFACES FOR DIGITALFABRICATION. IN PROCEEDINGS OF THE FIFTH INTERNATIONAL CONFERENCE ON TANGIBLE, EMBEDDED, AND EMBODIED INTERACTION, ACM, NEW YORK, NY, USA, TEI '11, 69–72.

WEICHEL, C., LAU, M., KIM, D., VILLAR, N., AND GELLERSEN, H.W. MIXFAB: A MIXED-REALITY ENVIRONMENT FOR PERSONAL FABRICATION. IN PROCEEDINGS OF THE SIGCHI CONFERENCE ON HUMAN FACTORS IN COMPUTING SYSTEMS (CHI '14), 3855-3864, 2014.