Rapid and Shape-Changing Digital Fabrication Using Magnetic Thermoplastic Material

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ABSTRACT

In this research, we propose a digital fabrication method that can print reusable objects rapidly using the clay material.

Therefore, we developed a magnetic force control device and a magnetic thermoplastic material that deforms dynamically. When the user creates a shape model on the screen, the clay material instantly changes to the shape of the designed model. The user can confirm the shape in a short time, and the material can be reused. In this paper, we describe the design and implementation of magnetic materials and control devices, evaluation, and future work.

CCS CONCEPTS

• **Human-centered computing** → *Interactive systems and tools.*

KEYWORDS

Digital Fabrication, Prototyping, Digital Materialization

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1 INTRODUCTION

In recent years, digital fabrication technology such as 3D printers has begun to widespread. However, most of the current 3D printing technologies print objects layer by layer, it requires a lot of printing time. Furthermore, it is difficult to change the shape after the printing process. Rapid and reusable 3D fabrication method leads to the reduction of material cost and printing time.

The researchers proposed rapid and reusable fabrication techniques. ProtoMold [Yamaoka and Kakehi 2017] is a technology for forming a 2.5D object rapidly using a vacuum forming and a pin display. BlowFab [Yamaoka et al. 2017] is a method to create a 3D inflatable object using a laser cutter. Since these shaped objects have a sheet shape or a hollow structure, it is difficult to print a solid structure.

Many types of research have been proposed similar approaches using magnetic materials. Programmable Liquid Matter [Tokuda et al. 2017] makes a circuit by moving a magnetic fluid with an electromagnet, but the magnetic material does not harden. Joshipura et al. proposed a technique for printing a 3D object by stacking liquid drops of a liquid metal [Joshipura et al. 2015], but it takes a lot of printing time. In this research, we propose a rapid fabrication method by controlling a magnetic clay material. When the user creates a shape model on the screen, the clay material instantly changes to the shape of the designed model (Figure 1).

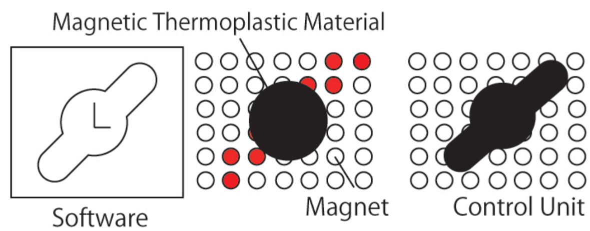

Figure 1: Concept of our process.

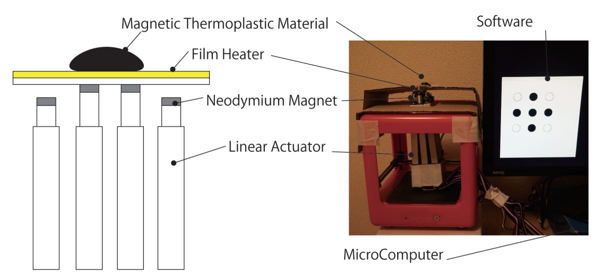

Figure 2: System of our fabrication techniques.

2 HARDWARE

Our system consists of shape-changing clay material, a magnetic force control unit, a microcomputer, and a computer connected to the software (Figure 2). Clay material consists of thermoplastic material and iron sand.

The melting point of the thermoplastic material (polyethylene) is about 40 degrees Celsius, and it is possible to switch between solid and liquid states by heating. By mixing iron sand with this thermoplastic material, the shape can be controlled by the magnetic force during softening. The magnetic force control unit consists of a linear actuator (L12 Micro Linear Actuator, Actuonix Motion Devices Inc.) and multiple neodymium magnets and a heater (Ultra Heating Fabric, WireKinetics Co., LTD.). The heater melts the

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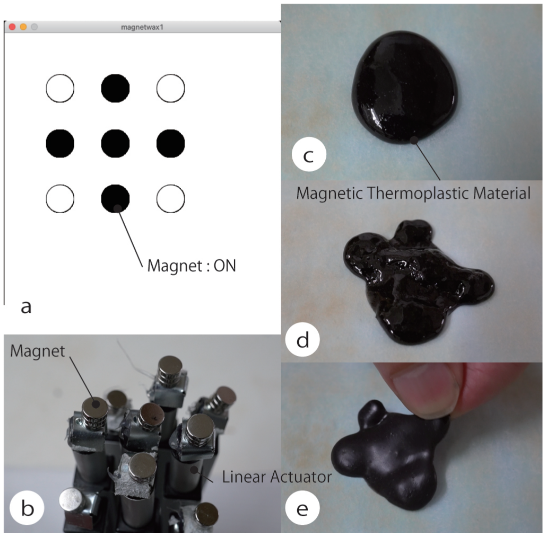

Figure 3: (a) The user designs shape with the software, (b) magnets move up and down, (c, d) melting material deforms and (e) the user can take the object.

magnetic thermoplastic plastic, and actuators move up and down to generate a magnetic force at an arbitrary position. The magnetic thermoplastic plastic gathers in the magnet, and the material is cured by turning off the heater.

This time, we arranged 3x3 actuators, and the diameter of the magnet is 5 mm. The printable size is 40 x 40 mm. The amount of thermoplastic material used this time was 1 g, and the number of iron sands was 0.5 g. The amount varies depending on the size of the printed object, the ratio of iron sands to plastic is preferably about 1: 2.

3 SOFTWARE

The user designs an arbitrary shape on the software developed using Processing (Figure 3 a). The software sends the created data of placements of magnets into the microcomputer (Arduino UNO). After sending the data, the actuator moves up and down, and arbitrary magnets hit the backside of the printing stage (Figure 3 b).

After the hardened material is placed on the printing stage, the material softens and deforms into the designed shape (Figure 3 c, d). Further, the thickness of the material can be controlled according to the distance between the magnet and the stage. For example, when the distance is short, a large number of iron sands gather, so that the thickness of the material increases.

Finally, the user can remove the printed object from the stage (Figure 3 e). After printing, the user can change the shape by hand or control unit repeatedly.

Using this method, we investigated the reproducibility of shapes. We created the arrangement of magnets indicated in Figure 4 a, the final printed shape is Figure 4 b. In another example, we created the arrangement of magnets indicated in Figure 4 c, the final printed shape is Figure 4 d.

Each printing time was 2 minutes for heating, 30 seconds for moving the magnetic material, and 2 minutes for curing by cooling. The resolution of the printed object was not sufficient, but the rough shape could be reproduced.

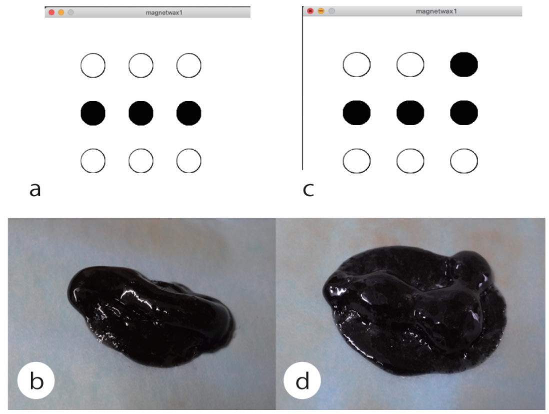

Figure 4: This method can print various shapes such as a line shape (a,b) and a L character shape (c,d).

4 CONCLUSION AND FUTURE WORK

In this paper, we proposed a rapid and reusable digital fabrication method that can deform a printed object using a clay magnetic thermoplastic material and a magnetic force controller. Using the developed tool, the user can reshape the object into a designed shape.

Current accuracy depends on the size of the actuator. In the future, we develop a high-resolution pin display by reducing the size of the actuator.

Furthermore, the current system creates a printed object with only one layer. We plan to create a 3D object consisting of multiple layers. For example, we plan to attach a magnet on the top of a robot arm, and the magnet moves in a wide area and can deform the objects from the side and the top.

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