Edible Lenticular Lens Design System

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ABSTRACT

Lenticular lenses are widely known as optical elements that change color depending on the viewing angle. By realizing this phenomenon in edible materials, it is possible to create a new gastronomic experience that significantly changes the appearance of food. In this study, we propose a system that supports the workflow from the design to the fabrication of edible lenticular lenses. The proposed system consists of lenticular lens design software and fabrication hardware. Users can design a visual effect of lenticular lenses by software simulation and fabricate the lenses by the knife cutting method using the hardware of the proposed system. In this study, the fabricated lenses were compared with the rendered ones. Furthermore, we confirm that the fabrication of the lenses is highly accurate and requires a short time.

Figure 1: Dish using edible lenticular lenses. This work depicts butterflies gathering on flowers. The lenses are used for the surrounding butterflies. The color of the wings of butterflies changes depending on the viewing angle.

CCS CONCEPTS

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

KEYWORDS

edible optics, lenticular lens, design tools, digital fabrication

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1 INTRODUCTION

Lenticular lenses are useful optical elements that are widely used for various purposes. For instance, changing colors depending on the viewing angle, camouflaging objects [1], and creating glasses-free stereoscopic vision. In recent years, research has been conducted to realize 3D-printed objects that appear different depending on the viewing angle. This is achieved by combining 3D printing technology and placing the lenticular lenses on the objects [8].

The research field of edible optics, which realizes conventional optical elements with edible materials, has the potential to extend existing technology to the realm of gastronomic experience. Previous research show examples including edible lenses and retroreflectors. In these cases, applications to the medical field and projection mapping for the food environment have been realized [2, 3]. Further, the field of molecular gastronomy has attempted to scientifically analyze the cooking process and create new cooking methods and culinary expressions based on the results. In this field, it is expected that the combination of scientific knowledge and culinary expression can create new tastes and gastronomic experiences.

Based on these research fields, we aimed to realize lenticular lenses with edible materials. Our goal is to induce various effects of the lenticular lens to the gastronomic experience. Figure 1 shows a dish using an edible lenticular lens designed in collaboration with chefs [5]. This edible lenticular lens can be introduced as a new service or dish in molecular gastronomy restaurants.

In this study, we present a system for designing an edible lenticular lens, which incorporates a simulation-based design tool and fabrication machine by a knife-cutting method. The proposed knife cutting method is one of the edible lenticular lens fabrication methods [7]. It is superior in terms of short time; however, it has problems with accuracy and reproducibility because of hand-cutting process. Furthermore, it is difficult to achieve an index of refraction (IOR) equivalent to that of conventional lens materials with edible materials. Thus, it is difficult to simulate the actual appearance of the edible lenses.

In the proposed system, users can design lenticular lenses with arbitrary specifications including pitch and curvature radius, and preview the effect of the lenticular lenses through ray-tracing simulations. The system also outputs a 3D model of the knife to fabricate the designed lens, and it can be cut from a jelly cube by hardware for high-accuracy, fast fabrication.

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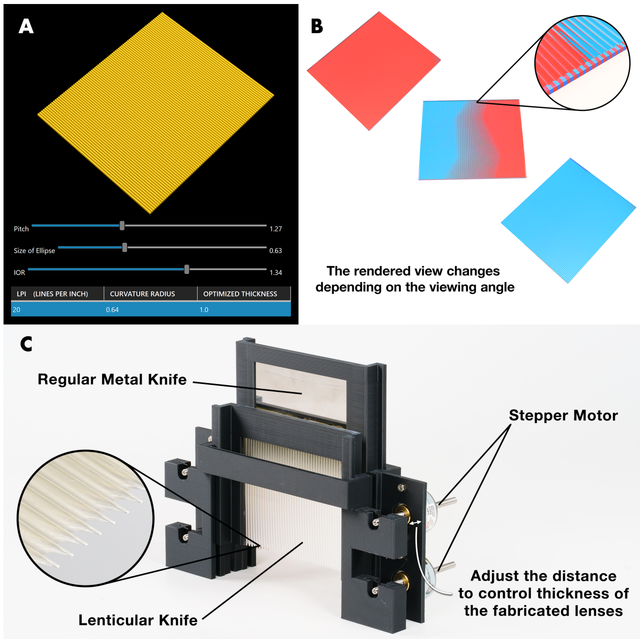

Figure 2: (A) Simulation interface for designing an edible lenticular lens, (B) Rendered view generated by our design tool, (C) System overview of the fabrication machine.

2 SYSTEM

This section describes the workflow of designing an edible lenticular lens using the proposed system. First, users input parameters including pitch, curvature radius (ellipse size), and refractive index to the system based on their specific objectives. The system then calculates the optimized lens thickness using these inputs and generates a 3D model of the lenticular lens based on the specified parameters. Users can preview the visual effect of the lens through ray-tracing simulation. Finally, the system outputs a 3D model of the knife with the inverse structure of the designed lenticular lens. Users can then 3D-print the knife and combine it with the fabrication machine to create the designed edible lenticular lens.

Design Tool. The design tool is a lenticular lens design software created by Rhinoceros and its plug-in Grasshopper. Users can generate a 3D model of a lenticular lens with arbitrary specifications including pitch and curvature radius by inputting parameters, and view its approximate shape in Grasshopper, as shown in Figure 2A. The simulation was rendered using ray tracing with V-Ray for Rhino. Real-time rendering allows users to interactively view the visual effect of the lens from the perspective of users, as shown in Figure 2B. The proposed system generates a 3D model with an optimized thickness calculated from user input parameters, based on the formula for determining the optimized thickness of a lenticular lens described in [4].

Fabrication Machine. The fabrication machine is a hardware for the knife cutting method, equipped with a steel knife of normal shape and a 3D-printed knife with the inverse structure of a lenticular lens. Users can create an edible lenticular lens of a designed shape by cutting off a jelly cube with a specified refractive index with two different types of knives. Parameters including the pitch and curvature radius of the lenticular lens are controlled by changing the knives, and the thickness is controlled by adjusting the distance between the two knives using stepper motors. Figure 2C shows an overview of the fabrication machine of the proposed system. The knife part is by an SLA (stereolithography) 3D printer (SATURN 2, ELEGOO) and resin (high toughness washable resin transparent color, SK Honpo). The hardware body is made by a fused deposition modeling 3D printer (M200 Plus, Zortrax) and filament (Z-HIPS, Zortrax). Owing to the requirement of high resolution to reproduce the fine structure of the lenticular lens, an SLA 3D printer with a resolution of 28.5μm was selected for the knife part.

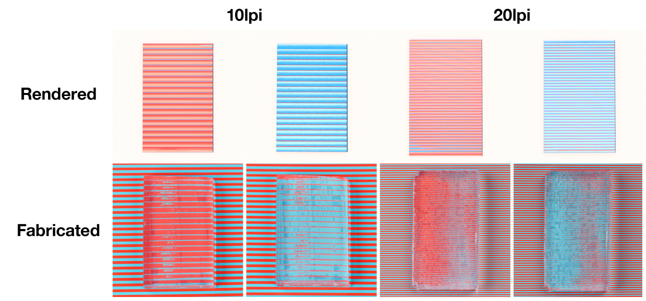

Figure 3: Comparison of fabricated and rendered views of the changing effect of the 10 lpi and 20 lpi lenses.

3 RESULT

The jelly cubes used to fabricate edible lenticular lenses consisted of gellan gum with an IOR of 1.34, similar to that used in a previous study[7]. In this study, lenticular lenses with a curvature radius of 1.61 mm and thickness of 5.34 mm for 10 lpi and with a curvature radius of 1.34 mm and thickness of 5.03 mm for 20 lpi were fabricated and verified the changing effect. The lenticular images were printed on a 3R glossy photo paper (Crispia Photo Paper, Epson) using a standard printer (SC-PX1VL, Epson). Figure 3 shows the results of the comparison between the fabricated and rendered lenses in terms of the changing effect. The fabricated image shows that the color of the lenses changed uniformly to red and blue, depending on the viewing angle. Structural colors also have the effect of changing color depending on the viewing angle [6]. However, lenticular color changing is superior to structural colors in that the type and angle of the changing color can be controlled in detail.

The time to fabricate the two types of lenses from the jelly cubes was approximately 10 minutes. This is a sufficiently short time to serve food in restaurants. The proposed system is useful in designing the visibility of edible lenticular lenses and fabricating them in a short time.

4 FUTURE WORK

In the future, we will investigate the effect of each pitch and the error range, and explore the possibility of realizing other visual effects for lenticular lenses such as the vanishing effect and glasses-free stereoscopic effect.

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