Physicalizing Sound with Chocolate: Exploring Shape Design Through 3D Printing and Melting Property

Nie Yakun†1 Kazuhiro Jo†2

Abstract: This study uses chocolate as a medium for sound physicalization, proposing a new way to physicalize sound by utilizing its melting property. Although sound is intangible, it plays an important role in everyday life. Through tests involving sound data mapping, food 3D printing, and temperature-controlled shape manipulation, this study aims to convert sound data into physical forms, enabling sound to be expressed through multiple senses. By utilizing chocolate, a widely used food material with the unique characteristic of melting near body temperature, this study attempts to change the shape of the chocolate through temperature control, creating various forms.

1. Introduction

Sound is ever-present in daily life, and unlike visual information, it is intangible, which often leads to it being overlooked. A Study suggests that sounds which evoke deep emotional resonance in listeners are referred to as "sonic gems"– short, precious sounds that they want to keep [1]. This further confirms the significant role sound plays in people's lives. On the other hand, the information conveyed by sound is not as direct as that of visual media, and sound can trigger associations with other sensory information. Many studies have confirmed crossmodal correspondences between sound and other senses, such as associations between sound and taste [2], and between sound and shapes [3]. These cross-sensory phenomena provide a foundation for representing sound through other sensory information, such as sound visualization.

However, making something tangible is important to people. For example, Elise van den Hoven et al. pointed out that "Comparisons of physical and digital media show that digital memorabilia are less salient and judged to be generally less important than their physical counterparts [4]." Here, we introduce another field: data physicalization. Data physicalization is the practice of mapping data to physical form [5]. Sound physicalization refers to converting sound data into tangible objects, thus expressing the characteristics of sound through multiple senses.

In this study, chocolate is used as a medium for sound physicalization. When melted, chocolate can be molded into various shapes, and once solidified, it can be preserved for long periods. It also comes in a variety of colors, flavors, and textures. Chocolate engages multiple senses, including taste, touch, smell, and sight. As such, chocolate is highly suitable as a medium for sound physicalization. Moreover, since chocolate is a popular and widely consumed food, using chocolate as a medium makes the concept of sound physicalization more accessible to the general public, bringing the research closer to everyday life.

2. Related work

There have been some studies that use chocolate as a material to transform sound into tangible forms. Gerbrand van Melle explored the physicalization of ambient sounds [6]. They digitally transformed the values of duration, spectrum, and amplitude of recorded sounds into x, y, and z values to distort a virtual ring. Then, they created chocolate shapes using 3D-printed molds. They held an exhibition showcasing these sound-chocolate rings, where audiences interacted with the recorded ambient sounds by eating the chocolate.

Kimiko Ryokai et al. used chocolate to physicalize laughter [7]. They developed two design approaches. The first design used thin, square chocolate pieces stacked as towers, with each layer representing one laugh. The second design involved stacking chocolate pieces of different sizes to represent different quantities and qualities (e.g., belly laugh, giggle) of laughter. When people picked up the chocolate, they would hear the corresponding laughter.

Although both studies used chocolate as a material, they primarily focused on its edibility. A unique feature of chocolate, compared to other moldable food materials like sugar, fruit puree, or bean paste, is its melting point, which is close to body temperature, allowing it to melt and solidify easily. This study focuses on the unique melting property of chocolate and aims to control its shape by adjusting temperature.

†1 Graduate School of Design, Kyushu University
†2 Faculty of Design, Kyushu University

3. Our work

3.1 Mapping Sound to 3D Models

The basic principle of mapping is based on the Bouba/Kiki effect. The majority of people match the nonsensical word “Bouba” with rounded patterns, while they match “Kiki” with more angular patterns instead [3]. Chen, Y.C. et al. used RF patterns as test shapes for the Bouba/Kiki effect, showing that when frequency, amplitude, and spikiness increased, RF patterns were more likely to be matched with “Kiki” than with “Bouba” [3]. In the first stage of design, the base shape used for mapping was the RF pattern, and the basic mapping principle was that high-frequency sounds correspond to more angular RF patterns, while low-frequency sounds correspond to more rounded RF patterns.

In this study, we use Grasshopper for parametric modeling. Grasshopper is a visual programming language and environment that runs within the Rhinoceros 3D computer-aided design (CAD) application[1]. As shown in the figure, by changing the parameters of the RF pattern, different model shapes can be obtained (Figure 1).

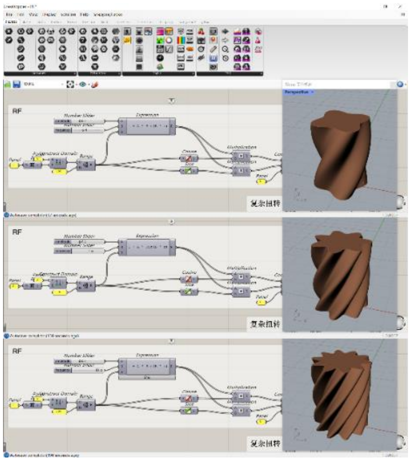

Figure 1 Models corresponding to RF patterns with different frequencies

In the second stage of the design, the base shape used was still the RF pattern, but we attempted to create hollow structures within the RF pattern (Figure 2). We also attempted to map MIDI melody lines on the Z-axis. The MIDI melody was analyzed in the software MAX[2], where we played the melody using the digital keyboard in MAX. The pitch data was then sent to Grasshopper via UDPsend. We also tried connecting a physical keyboard to the computer, playing the keyboard while obtaining real-time MIDI pitch data in MAX. In Grasshopper, the pitch data was mapped as the size of the cross-section on the Z-axis. As shown in Figure 3 and Figure 4, we can observe the models corresponding to different MIDI melody lines.

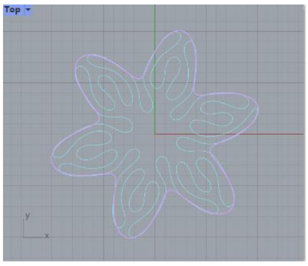

Figure 2 Hollow structures within the RF pattern

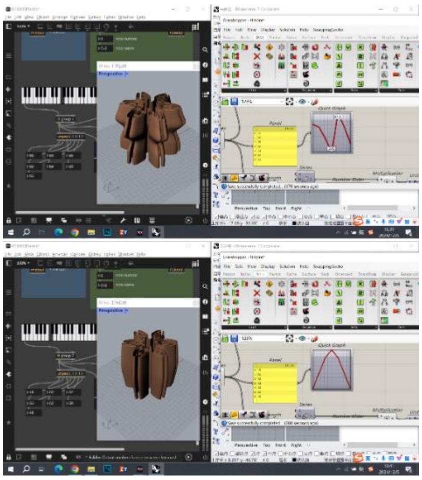

Figure 3 The MIDI data from the digital keyboard in MAX was sent to Grasshopper via UDPsend (on the right is the Grasshopper interface, and on the left are the MAX interface and the Grasshopper model preview window)

Figure 4 The model shape in Grasshopper changes according to the pitch of the MIDI notes played

1 https://www.grasshopper3d.com/
2 https://cycling74.com/products/max

3.2 Chocolate 3D Printing Testing

In this study, we used the Foodini food 3D printer [8]. After baking the model from Grasshopper into Rhinoceros, they were exported as STL file formats for 3D printing. The Foodini 3D printer can print various types of food and is not specifically designed for chocolate. This printer has a heating system but no cooling system, so the printing quality is heavily influenced by the chocolate's melting state.

We first conducted 3D printing tests with the design from the first stage in the summer of 2024. We used dark chocolate with 50% cocoa content and tested with chocolates of varying melt degrees (more liquid or more paste-like). The paste-like chocolate produced the best printing results. We also attempted to print white chocolate. The printed samples are shown in Figure 5.

Figure 5 The front and perspective views of two dark chocolate samples (the left with a frequency of 9 and amplitude 0.1, and the right with a frequency of 7 and amplitude 0.4), and the perspective view of a white chocolate sample (it deformed at the base due to its softer texture)

In the winter of 2024, we tested the design from the second stage. We found that due to the lower room temperature in winter, the chocolate solidified very quickly, which caused issues with extrusion. As a result, we temporarily switched to mashed potato for testing. The hollow structure we designed had gaps that were too small, and as a result, the hollow parts were not clearly visible in the 3D print, as shown in Figure 6.

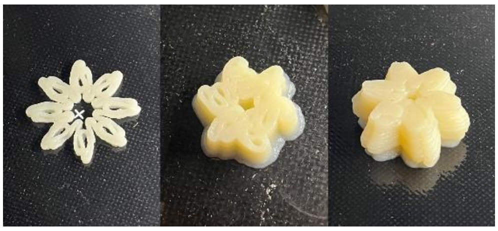

Figure 6 Hollow structure printed with mashed potatoes (the printed paths are visible in the samples, but the hollow structure is not very obvious)

However, by comparing the results from the summer and winter prints, we noticed that temperature is a crucial factor in chocolate 3D printing. Although the differences in printing results caused by temperature changes represent an imperfection, this is also one of the unique characteristics of chocolate. Therefore, we conducted further 3D printing tests at different temperatures.

3.3 3D Printing Tests at Different Temperatures

The heating temperature of the Foodini printer needs to be set before printing, and it has a preheating function. During the printing process, the capsule continues to heat, keeping the chocolate at the set temperature. Although Foodini has a heating system, if the temperature of the chocolate placed inside differs too much from the set temperature, it may cause uneven heating of the chocolate. Therefore, before printing, we melted the chocolate, let it cool to the desired temperature, and then filled the printing capsule with the chocolate paste. Then we kept the chocolate at the current temperature by setting the heating temperature. By adjusting the cooling degree of the chocolate and the printing temperature settings, we obtained chocolate pastes with different viscosities.

In this test, we used the design from the first stage. The same model was used for each print, with only the chocolate temperature changed. As shown in Figure 7, the temperature settings from left to right were 29°C, 30°C, 31°C, 32°C, 33°C, and 34°C. Since the temperature of the chocolate cannot be precisely measured during the printing process, there may be slight differences between the set and actual temperatures. Based on the current printing results, 31°C appears to be the turning point for the chocolate's supporting strength. Below 31°C, the chocolate paste has stronger support, and although small fusion occurs between layers, the structure does not collapse. Above 31°C, the layers merge, making it difficult to maintain the printed shape, resulting in a melted visual effect.

Figure 7 Chocolate samples printed with the same model (the temperatures from left to right were 29°C, 30°C, 31°C, 32°C, 33°C, and 34°C)

Although the printing results at higher temperatures differ significantly from the original model, the printed path is still visible. This phase of temperature testing is relatively simple, but with more precise temperature control and by experimenting with different types of chocolate, more effects caused by melting can be explored.

3.4 Temperature Control System Prototype

Based on the above tests, a temperature control system needs to be designed for more precise temperature regulation. At this stage, we created a simple prototype for heating by Arduino, as shown in Figure 8. The heating effect is achieved through a Peltier module, which is a thermal control module that has both "warming" and "cooling" effects. The current temperature value is obtained through a temperature sensor, and when it is below the target value, the system starts working. When the temperature exceeds the target value, it stops, thus allowing the Peltier module to heat to the desired temperature.

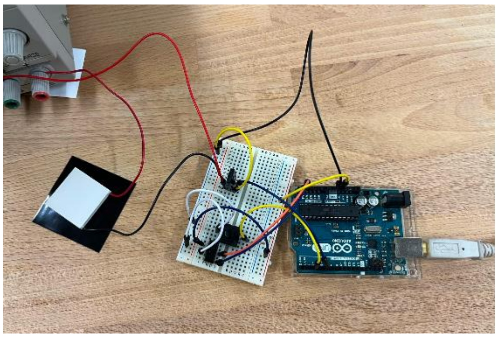

Figure 8 Temperature Control System Prototype (the Peltier module is located on the far left)

4. Discussion and the next steps

Currently, sound physicalization typically involves generating shapes directly from sound data. However, unlike traditional physicalization methods, this study introduces an emerging approach of controlling chocolate melting through data. By utilizing the unique properties of chocolate, new possibilities for sound physicalization are explored.

The next step is to refine the prototype design of the temperature control system and attempt to control the heating system with sound data. For example, the system could heat to different temperatures with changes in frequency or volume. Through more precise chocolate 3D printing tests, we can better understand the impact of temperature on the properties of chocolate and test with different chocolate compositions. If the temperature control system is placed on base of the Foodini printer, it could create varying melting effects when the chocolate comes into contact with the base, combining 3D printing with melting effects.

Another important aspect is the type of sound. Currently, the MIDI signals used in the test are a simple form of sound, suitable for the initial test. However, the type of sound used is crucial in determining whether the concept of sound physicalization can be effectively conveyed. Different types of sound may evoke different feelings, such as ambient sounds, music, or human voices. In the next step, we plan to collect participants' feedback through interviews to understand their thoughts on different types of sound and assess which type of sound most effectively conveys the concept of sound physicalization.

Once the appropriate sound type is determined, we will refine the mapping relationship between sound and the 3D model based on the characteristics of the corresponding audio data. Subsequently, we will invite participants to take part in testing and gather their feedback when they receive the chocolate object, to assess whether they can perceive sound physicalization and further optimize the design.

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