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From Dribbling Honey to Non-planar 3D-Printing; Coiling becomes Craft

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Figure 1: 3D printing TPU in a non-planar style where the material dribbles and falls down, rope coiling to craft unique textures.
Photo: Marica De Michele

ABSTRACT

Anyone who has watched a child play with soft semi-liquid materials like honey, frosting, or slime, sees the fascinating interplay between design and physics. Many of us remember these experiences from our own childhood (or maybe not that long ago). These materials dribble and coil as they stack upon themselves when we drop them onto surfaces like cakes from small heights. This ludic behavior represents a physical phenomenon known as rope coiling. Recent research in 3D printing of clay and plastic has started to wonder how rope coiling can be leveraged to create new textures and textile-like structures through non-planar 3D Printing. These provide new tactile experiences in objects like cups and visual experiences in things like lamps. In this demonstrator, we invite researchers and practitioners to return to their childhood and dribble edible materials to understand how to advance additive manufacturing through interactive printing.



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CCS CONCEPTS

• **Human-centered computing** → HCI design and evaluation methods; Interaction design process and methods.

KEYWORDS

Interactive 3D Printing, Rope Coiling, Ludic Play, Digital Fabrication, Additive Manufacturing, Non-planar

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1 INTRODUCTION

Do you remember playing with honey as a child, watching the bead of honey fall off the spoon into a coiled mound of liquid that slowly sinks back into the pool of honey? The ludic play of honey dripping from a bottle or spoon, forming coils, embodies the complexity of fluid dynamics in a manner both simple and intuitively understandable. This natural curiosity, rooted in our earliest playful experiences, offers a lens through which we can re-envision the interaction paradigms of 3D printing technologies. By translating the tangible dynamics of rope coiling observed in viscous fluids like honey, to the digital manipulation of soft materials like



Figure 2: A child dribbling honey onto a plate, note the coil shape the honey makes as it lands onto the plate.

TPU, this demonstrator uncovers ways to make digital fabrication more tangible, intuitive, and engaging by changing the system of fabrication.

Advancements in the realm of personal fabrication [3] are uncovering new design features inherent in the 3D printing design space

[6, 19, 21, 22]. A notable area of exploration within this field is interactive fabrication, which aims to facilitate in-situ decision-making during 3D printing. Willis et al. [26] were among the first to coin the term, and the concept has since gained traction among other researchers [12, 15, 16, 25]. These studies effectively decrease the borders between design and fabrication, allowing for the emergence of artifacts that share more with traditional crafting processes.

Over the past decade, researchers within the DIS community have focused on 'Being the Machine' [4] leading to new forms of machines and machine hacking [2] and the need for deeper process insight in different types of digital fabrication [8]. There is an opportunity to look at digital fabrication through ludic experiences with machines [17, 20], the process of design [7, 10] and the interaction of the things they make [1, 24]. Moreover, rope coiling has started to enter the domain of 3D printing [18, 22] and there is much to be done with it. The same rope coiling phenomenon can also frequently be observed in ceramic printing, a space that has had many recent contributions [5, 9, 13, 23, 27]. We also see areas where foams are used in design where rope coiling could be important [11, 14].

2 HAVING FUN WITH ROPE COILING

Our demonstrator offers three experiences that range from fun to serious fun in honey, frosting and 3D printing.

2.1 The Ludic Experience of Dribbling Honey

Childhood experience involves the playful exploration of materials that behave in curious and often unexpected ways. Honey, see Fig. 2, is a viscous fluid that creates fascinating patterns when dribbled from a height. Under the influence of gravity and depending on the height and rate at which it is poured, honey naturally forms coiling patterns as it hits a surface. This phenomenon, known as rope coiling, varies dramatically with changes in pouring rate, height, and the honey's viscosity. These variables alter the diameter, thickness, and shape of the resulting coils, providing a visually engaging and tactile form of play.

2.2 The Ludic Experience of Cake Decorating with Frosting

Building on dribbling honey, the use of frosting introduces a different dimension. Frosting, while similar to honey in its malleability and flow, possesses a thicker consistency that allows the creation of more solid, stable forms.

As participants experiment with frosting, see Fig. 3, they engage in a process that is not just about watching it flow, but actively crafting and stacking shapes. The frosting's thickness supports the formation of tighter and wider coils, which can be layered vertically, offering a direct and tactile way to understand the effects of material behavior on structural outcomes.

2.3 The Ludic Experience of 3D Printing

3D printing typically uses G-code, a programming language that instructs the machine on how to build an object layer by layer. Our project deviates from the traditional layer-by-layer deposition method to one that allows dynamic changes in the printing process to facilitate the creation of structures by rope coiling. Our initial



Figure 3: When frosting on cake where the designer follows a circular shape (seen as the green circle on the left) and the coils illustrated in purple emerge in varying patterns depending upon speed, height and pressure. The designer can stack multiple layers (right panel) to see the subtle differences in stacking as the rope coiling process.

attempts involved manually writing G-code that simulated the rope coiling effect. While these early efforts yielded promising results, they lacked ludic interactivity and flexibility that allows the designer's intuition of the material's dynamic behavior to be more directly translated into 3D printing actions. We found these to be critical aspects of the experience.

To transcend these limitations, we developed a custom controller interface, see fig. 4, significantly altering the hardware of our 3D printer to allow real-time interaction during the printing process. This controller integrates a slider and two rotary encoders, empowering designers to dynamically adjust the printing parameters that are critical to the coiling behavior of the material, akin to a child playfully squeezing a bottle of honey or frosting. Specifically, the slider controls the vertical movement of the nozzle, enabling designers to alter the height at which the material is extruded, while the rotary encoders manage the speed and flow rate of the material. While various materials could be used, Thermoplastic Polyurethane (TPU) inherent flexibility and strength allow it to maintain structural integrity even when printed in complex, non-planar shapes that embody the rope coiling effect. Source code developed for this project is available at <https://github.com/daan/nonplanar>.

3 DISCUSSION

3.1 The Role of Play in Understanding Complex Concepts

The transition from tangible, manual experiments to interactive digital fabrication, highlights how play can serve as a bridge between abstract concepts and their practical applications. By engaging with the material in a direct, hands-on manner, designers are not just passive recipients of information but active learners who adjust their actions based on the outcomes experienced. This engagement facilitated by ludic experiences enhances understanding and fosters a deeper appreciation for the creative possibilities inherent in materials like TPU, see fig.5.

4 CHALLENGES AND OPPORTUNITIES

While our research is in progress, challenges and opportunities have already presented themselves. Innovative textures, shapes, and forms emerge from the rope coiling approach that were previously difficult or impossible to achieve with traditional methods become accessible, inviting exploration and experimentation. By making the 3D printing process more interactive and responsive to designer input, this approach fosters greater engagement and encourages creativity and rapid iterations of printing strategies. Designers are not just modelers but co-creators, working with the material and machine to bring their visions to life. Also, the intersection of ludic experiences with digital fabrication encourages collaboration across disciplines, bringing together experts in material science, physics, HCI, design, and education. This cross-pollination of ideas can lead to innovative solutions and new research directions.

More challenging were the interface design and ensuring that the ludic experience translates to digital fabrication. Transitioning from experiences with edible materials to digital fabrication introduces challenges in calibrating the expectation of the designer with the ability of the 3D printers. Adjusting variables such as temperature,

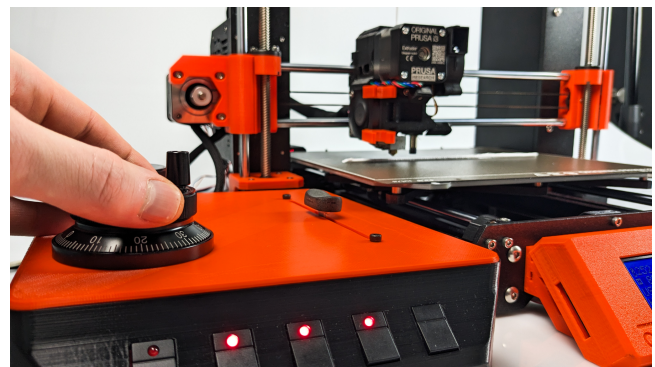


Figure 4: A control box developed to allow designers to interact with the height, flow and speed of the 3D printer while it is printing.



Figure 5: An upside-down diamond shape (created in Tinkercad) fabricated with the dribbled rope coiling technique where the height, speed and flow are interactively controlled. An internal detail of the texturing created is seen in the right panel, far different from traditional 3D printing.

pressure, and drop height to control the dynamic behavior of rope coiling requires a fine-grained control to allow reproducible results. This was seen when predicting printing behavior under varying conditions of rope coiling due to its flexible and elastic properties. Developing algorithms that can predict these behaviors is a significant computational challenge. Additionally, despite the ludic approach designed to simplify the concept, there remains a learning curve for designers to manipulate the various parameters (viscosity, speed, height, pressure) in a way that achieves their desired outcomes. More research is needed to ensure a delicate balance intuitive interaction while providing enough control to designers.

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