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

Alberts, Max; Nachtigall, Troy Robert; Doubrovski, Zjenja; Saakes, Daniel

DOI
10.1145/3656156.3665434

Publication date
2024

Document Version
Final published version

Published in
DIS '24 Companion

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

Max Alberts
Eindhoven University of Technology
Eindhoven, NL
m.alberts@student.tue.nl

Troy Nachtigall
Eindhoven University of Technology,
Amsterdam Univeristy of Applied Sciences
Eindhoven, Amsterdam, NL
t.r.nachtigall@tue.nl

Daniel Saakes
University of Twente
Enschede, NL
d.p.saakes@utwente.nl

Zjenja Dubrovski
Delft University of Technology
Delft, NL
e.l.doubrovski@tudelft.nl

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.

DIS Companion '24, July 01–05, 2024, IT University of Copenhagen, Denmark

ACM ISBN 979-8-4007-0632-5/24/07
https://doi.org/10.1145/3656156.3665434

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

ACM Reference Format:
Max Alberts, Troy Nachtigall, Daniel Saakes, and Zjenja Dubrovski. 2024. From Dribbling Honey to Non-planar 3D-Printing; Coiling becomes Craft. In *Designing Interactive Systems Conference (DIS Companion '24), July 01–05, 2024, IT University of Copenhagen, Denmark.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3656156.3665434

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

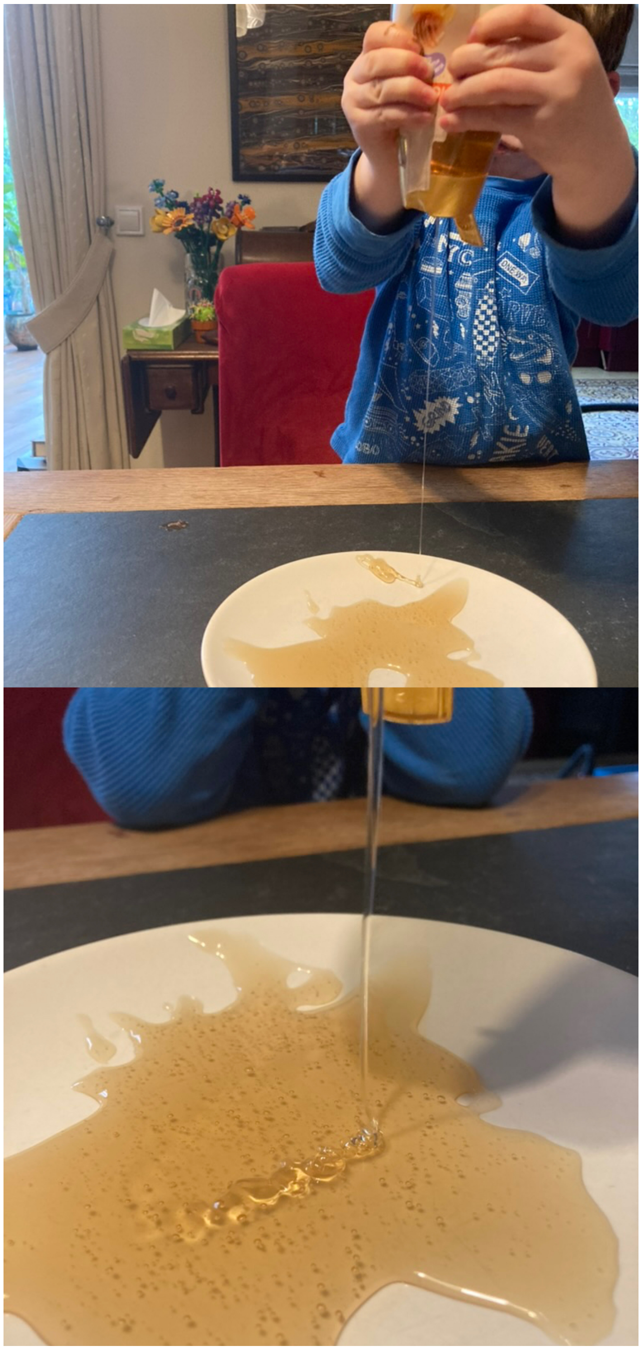

Figure 2: A child dribbling honey onto a plate, note the coil shape the honey makes as it lands onto the plate.

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,

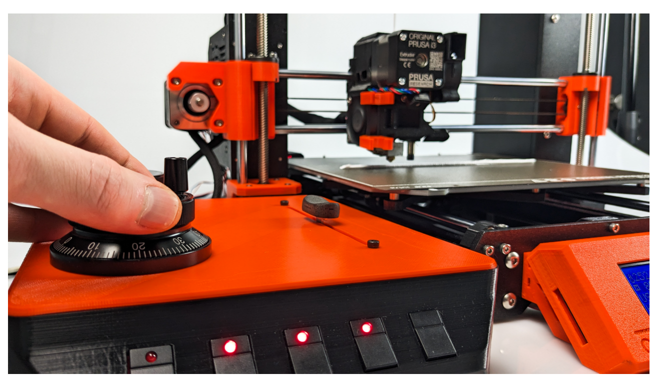

Figure 4: A control box developed to allow designers to interact with the height, flow and speed of the 3D printer while it is printing.

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.

ACKNOWLEDGMENTS

Thank you to the Dutch 4TU research institute Design United Probe Funding for supporting this joint research.

REFERENCES

[1] Davide Jose Nogueira Amorim, Troy Nachtigall, and Miguel Bruns Alonso. 2019. Exploring mechanical meta-material structures through personalised shoe sole design. *Proceedings of the ACM Symposium on Computational Fabrication - SCF '19*, 1–8. https://doi.org/10.1145/3328939.3329001

[2] Kristina Andersen, Ron Wakkary, Laura Devendorf, and Alex McLean. 2019. Digital crafts-machine-ship: creative collaborations with machines. *Interactions* 27, 1 (Dec 2019), 30–35. https://doi.org/10.1145/3373644

[3] Patrick Baudisch and Stefan Mueller. 2017. Personal Fabrication. *Foundations and Trends in Human–Computer Interaction* 10, 3-4 (2017), 165–293. https://doi.org/10.1561/1100000055

[4] Laura Devendorf and Kimiko Ryokai. 2014. Being the machine: exploring new modes of making. In *Proceedings of the 2014 Companion Publication on Designing Interactive Systems* (Vancouver, BC, Canada) *(DIS Companion '14)*. Association for Computing Machinery, New York, NY, USA, 33–36. https://doi.org/10.1145/2598784.2602775

[5] Camila Friedman-Gerlicz, Deanna Gelosi, Fiona Bell, and Leah Buechley. 2024. WeaveSlicer: Expanding the Range of Printable Geometries in Clay. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems (CHI'24)*. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3613904.3642622

[6] Andrew Gleadall. 2021. FullControl GCode Designer: Open-source software for unconstrained design in additive manufacturing. *Additive Manufacturing* 46 (2021), 102109. https://doi.org/10.1016/j.addma.2021.102109

[7] Bruna Goveia da Rocha, Johannes M. L. van der Kolk, and Kristina Andersen. 2021. Exquisite Fabrication: Exploring Turn-taking between Designers and Digital Fabrication Machines. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan,) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 434, 9 pages. https://doi.org/10.1145/3411764.3445236

[8] Mare Hirsch, Gabrielle Benabdallah, Jennifer Jacobs, and Nadya Peek. 2023. Nothing Like Compilation: How Professional Digital Fabrication Workflows Go Beyond Extruding, Milling, and Machines. *ACM Trans. Comput.-Hum. Interact.* 31, 1, Article 13 (nov 2023), 45 pages. https://doi.org/10.1145/3609328

[9] Sarah Homewood, Harvey Bewley, and Laurens Boer. 2019. Ovum: Designing for Fertility Tracking as a Shared and Domestic Experience. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (San Diego, CA, USA) *(DIS '19)*. Association for Computing Machinery, New York, NY, USA, 553–565. https://doi.org/10.1145/3322276.3323692

[10] Rilla Khaled, Vero Vanden Abeele, Maarten Van Mechelen, and Asimina Vasalou. 2014. Participatory design for serious game design: truth and lies. In *Proceedings of the First ACM SIGCHI Annual Symposium on Computer-Human Interaction in Play* (Toronto, Ontario, Canada,) *(CHI PLAY '14)*. Association for Computing Machinery, New York, NY, USA, 457–460. https://doi.org/10.1145/2658537.2659018

[11] Doheon Kim, Joongi Shin, and Daniel Saakes. 2020. Foam Sheets as Material for Fabricating Large and Functional Soft Objects. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS' 20 Companion)*. Association for Computing Machinery, New York, NY, USA, 239–244. https://doi.org/10.1145/3393914.3395866

[12] Junbong Kim, Chen Zheng, Hiromi Takahashi, Mark D. Gross, Daniel Ashbrook, and Tom Yeh. 2018. Compositional 3D Printing: Expanding and Supporting Workflows towards Continuous Fabrication. In *Proceedings of the 2nd Annual ACM Symposium on Computational Fabrication*. New York, NY, USA, 1–10.

[13] Henry Lin, Ron Wakkary, and Doenja Oogjes. 2019. The Tilting Bowl: Electronic Design for a Research Product. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (San Diego, CA, USA) *(DIS '19)*. Association for Computing Machinery, New York, NY, USA, 345–357. https://doi.org/10.1145/3322276.3323701

[14] Mehmet Ozdemir and Zjenja Doubrovski. 2023. Xpandables: Single-filament Multi-property 3D Printing by Programmable Foaming. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany,) *(CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, Article 323, 7 pages. https://doi.org/10.1145/3544549.3585731

[15] Huaishu Peng, Jinha Lee, Daniel Saakes, Amit Zoran, Bongjin Koo, and Patrick Baudisch. 2018. RoMA: Interactive Fabrication with Augmented Reality and a Robotic 3D Printer. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. New York, NY, USA, 1–12.

[16] Huaishu Peng, Robert Wu, Steve Marschner, and Francois Guimbretière. 2016. On-The-Fly Print: Incremental Printing While Modelling. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. New York, NY, USA, 887–896.

[17] Miguel Sicart and Irina Shklovski. 2020. 'Pataphysical Software: (Ridiculous) Technological Solutions for Imaginary Problems. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands,) *(DIS '20)*. Association for Computing Machinery, New York, NY, USA, 1859–1871. https://doi.org/10.1145/3357236.3395526

[18] Blair Subbaraman and Nadya Peek. 2022. Demonstrating p5.fab: Direct Control of Digital Fabrication Machines from a Creative Coding Environment. In *Adjunct Proceedings of the 35th Annual ACM Symposium on User Interface Software and Technology* (Bend, OR, USA) *(UIST '22 Adjunct)*. Association for Computing Machinery, New York, NY, USA, Article 70, 3 pages. https://doi.org/10.1145/3526114.3558646

[19] Bharath Subbaraman and Nadya Peek. 2022. p5.fab: Direct Control of Digital Fabrication Machines from a Creative Coding Environment. In *Designing Interactive Systems Conference*. Virtual Event, Australia, 1148–1161.

[20] Blair Subbaraman and Nadya Peek. 2023. 3D Printers Don't Fix Themselves: How Maintenance is Part of Digital Fabrication. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference* (Pittsburgh, PA, USA,) *(DIS '23)*. Association for Computing Machinery, New York, NY, USA, 2050–2065. https://doi.org/10.1145/3563657.3595991

[21] Hiromi Takahashi and Jun Kim. 2019. 3D Printed Fabric: Techniques for Design and 3D Weaving Programmable Textiles. In *Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology*. New York, NY, USA, 43–51.

[22] Hiromi Takahashi and Hiroyuki Miyashita. 2017. Expressive Fused Deposition Modeling by Controlling Extruder Height and Extrusion Amount. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. New York, NY, USA, 5065–5074.

[23] Mert Toka, Samuelle Bourgault, Camila Friedman-Gerlicz, and Jennifer Jacobs. 2023. An Adaptable Workflow for Manual-Computational Ceramic Surface Ornamentation. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology* (San Francisco, CA, USA,) *(UIST '23)*. Association for Computing Machinery, New York, NY, USA, Article 24, 15 pages. https://doi.org/10.1145/3586183.3606726

[24] Vasiliki Tsaknaki. 2021. The Breathing Wings: An Autobiographical Soma Design Exploration of Touch Qualities through Shape-Change Materials. In *Proceedings of the 2021 ACM Designing Interactive Systems Conference* (Virtual Event, USA) *(DIS '21)*. Association for Computing Machinery, New York, NY, USA, 1266–1279. https://doi.org/10.1145/3461778.3462054

[25] Christian Weichel, John Hardy, Jason Alexander, and Hans Gellersen. 2015. ReForm: Integrating Physical and Digital Design through Bidirectional Fabrication. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software and Technology*. Charlotte, NC, USA, 93–102.

[26] Karl D.D. Willis, Cheng Xu, Kang-Jin Wu, Golan Levin, and Mark D. Gross. 2010. Interactive fabrication: new interfaces for digital fabrication. In *Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction*. Funchal, Portugal, 69–72.

[27] Clement Zheng, Bo Han, Xin Liu, Laura Devendorf, Hans Tan, and Ching Chiuan Yen. 2023. Crafting Interactive Circuits on Glazed Ceramic Ware. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany,) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 474, 18 pages. https://doi.org/10.1145/3544548.3580836