4840-1055:
Non-Research Tips for Information Science Researchers
情報科学研究補助技法 (Summer 2024)

Videos

(+ demonstration of what I've taught for three weeks)

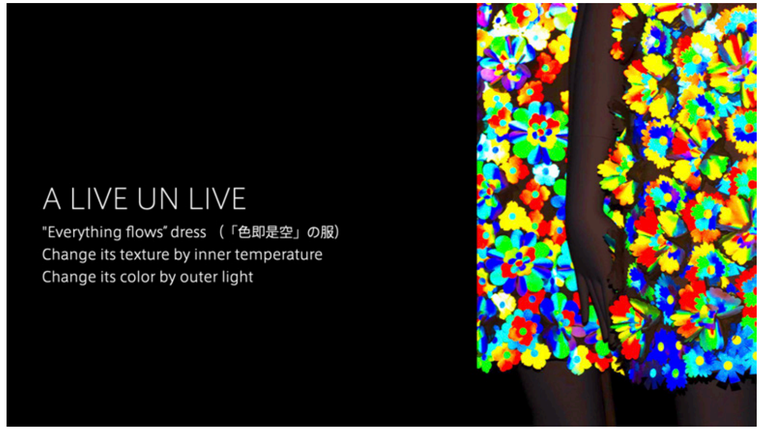
Koya Narumi | Keio University | https://narumi.me/

“Interesting and unpublished” is equivalent to “non-existent.”

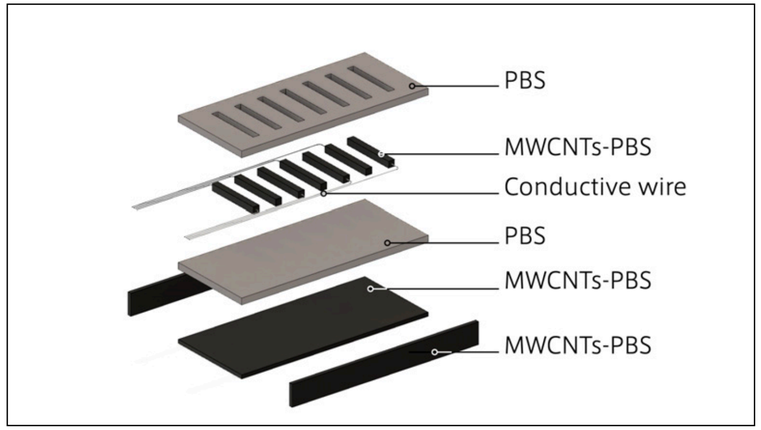
– George Whitesides

Let’s publish your achievement **effectively and beautifully.**

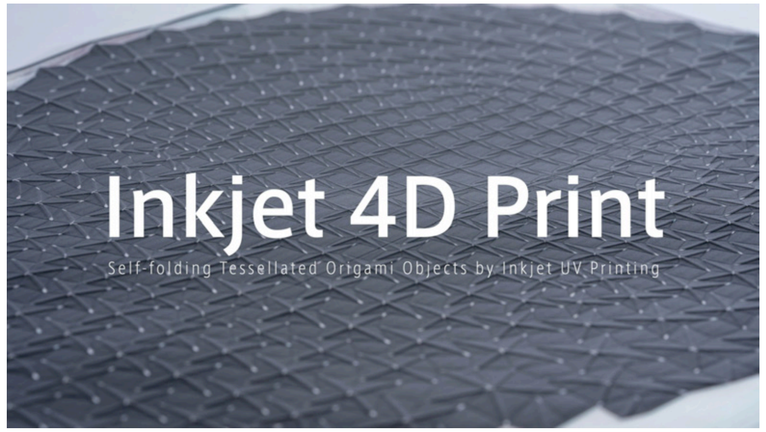
Three presentation methods



Week 3: **Slides**



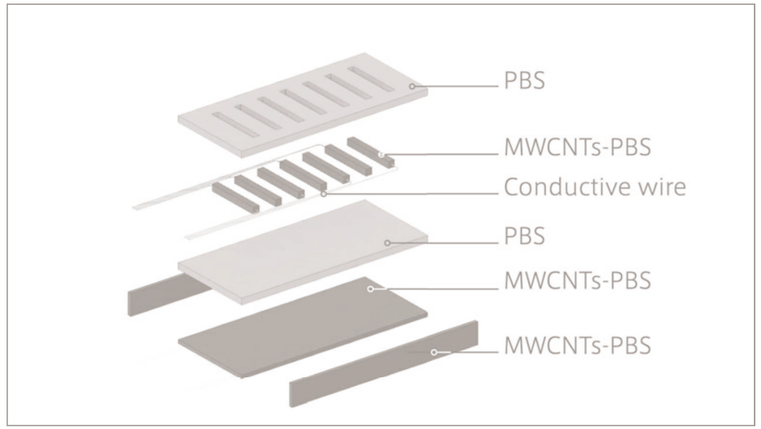
Week5: **Figures**



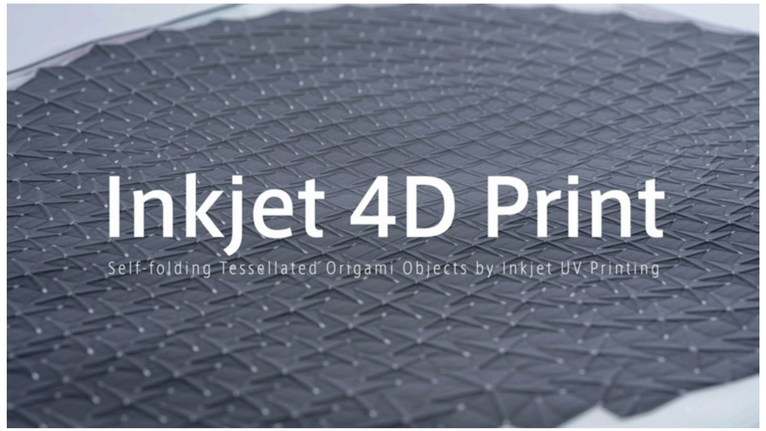
Week6: **Videos**

Three presentation methods

Week 3: **Slides**



Week5: **Figures**



Week6: **Videos**

Today's topics

Video-shooting environment

I like to take videos **in the same environment as photos**.

Video examples from my videos

Six video tips from my past videos.

Other video examples

Let's check **other great videos**.

VIDEO-SHOOTING ENVIRONMENT

Disclaimer: I'm not a videographer

I'll just share my experience of video-shooting.
Professionals are more professional.

Our video-shooting setup

Diffused video light x3 (two diffusers, one umbrella)
Black, white, and other colored backgrounds
Sony α7III

I use totally **the same setup for photo-shooting and video-shooting**.
This is not the best for photos, but **very convenient and mostly fine enough**.

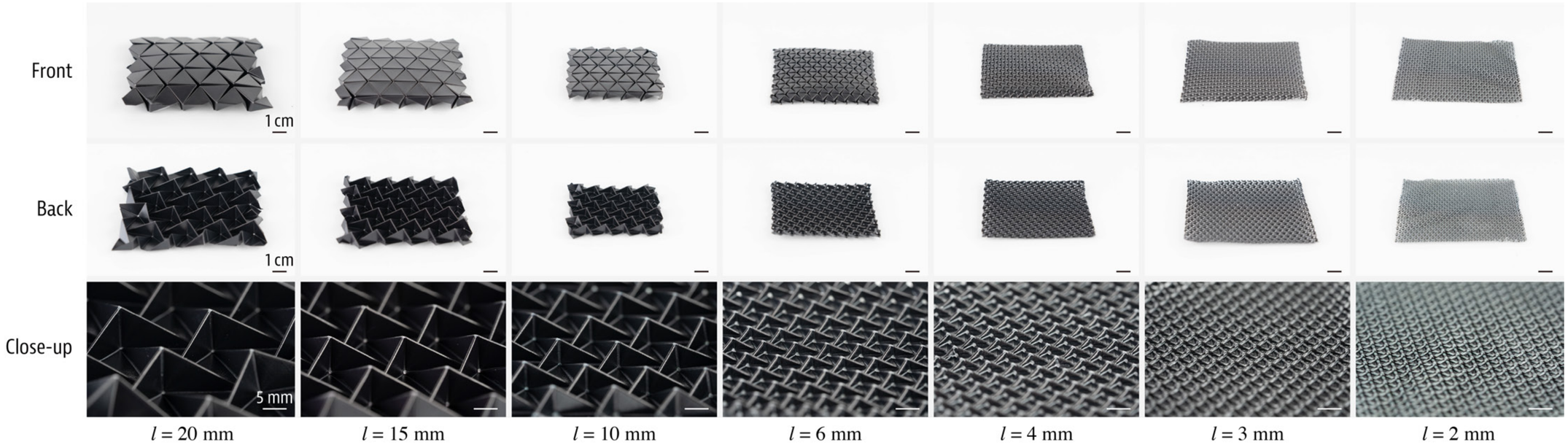
NOTE: For more serious photos, strobe is better

If you only need still photos, **strobes are better** than video lights.

But I like to use **video lights** to take photos and movies **at the same time**.

[1] Godox AD300Pro, Amazon

NOTE: Take movies as well in photo-shooting

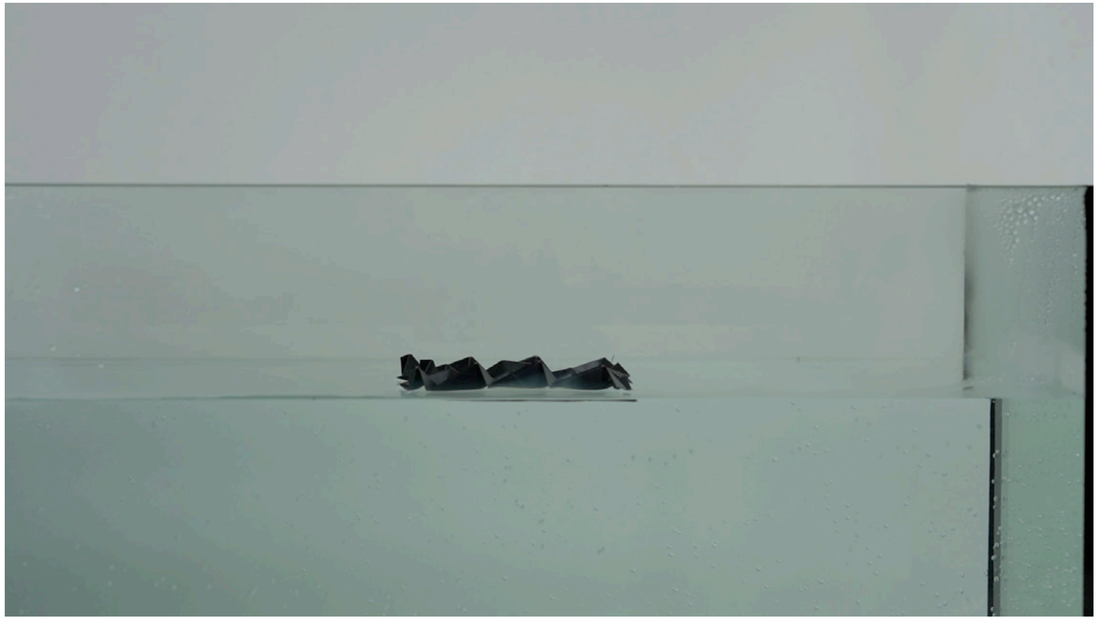


Photos for a figure

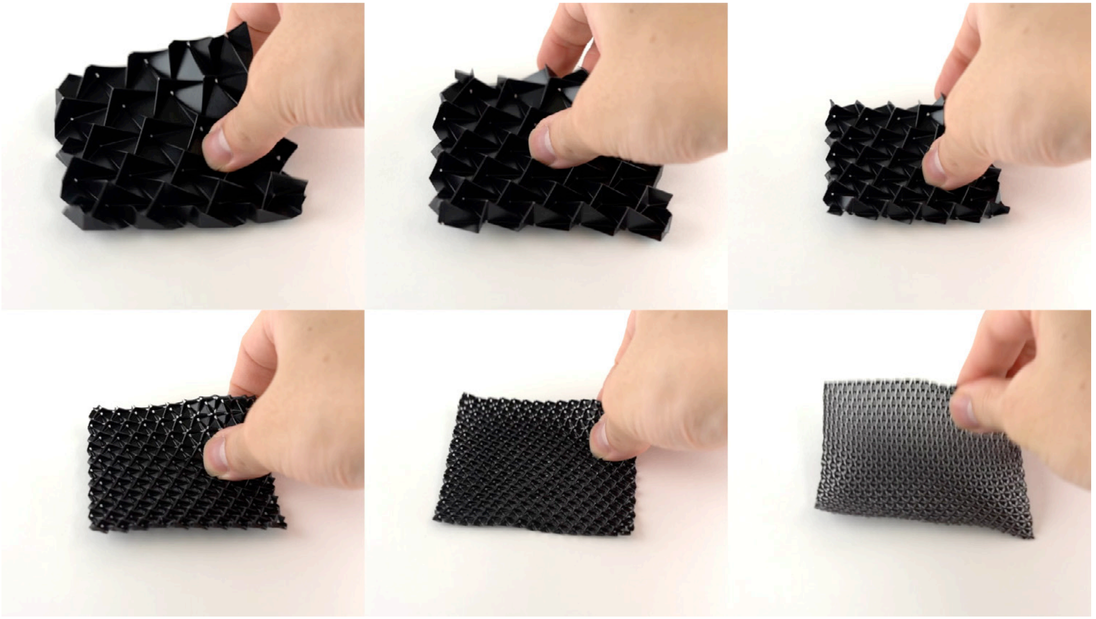
Short video clips are unexpectedly useful.
Let's always **take short movies as well when you take photos**.

[1] Narumi and Koyama et al., Inkjet 4D Print, ACM TOG 2023.

NOTE: Take movies as well in photo-shooting



Videos taken at the same time (raw)



Videos taken at the same time

Short video clips are unexpectedly useful.
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[1] Narumi and Koyama et al., Inkjet 4D Print, ACM TOG 2023.

Lens

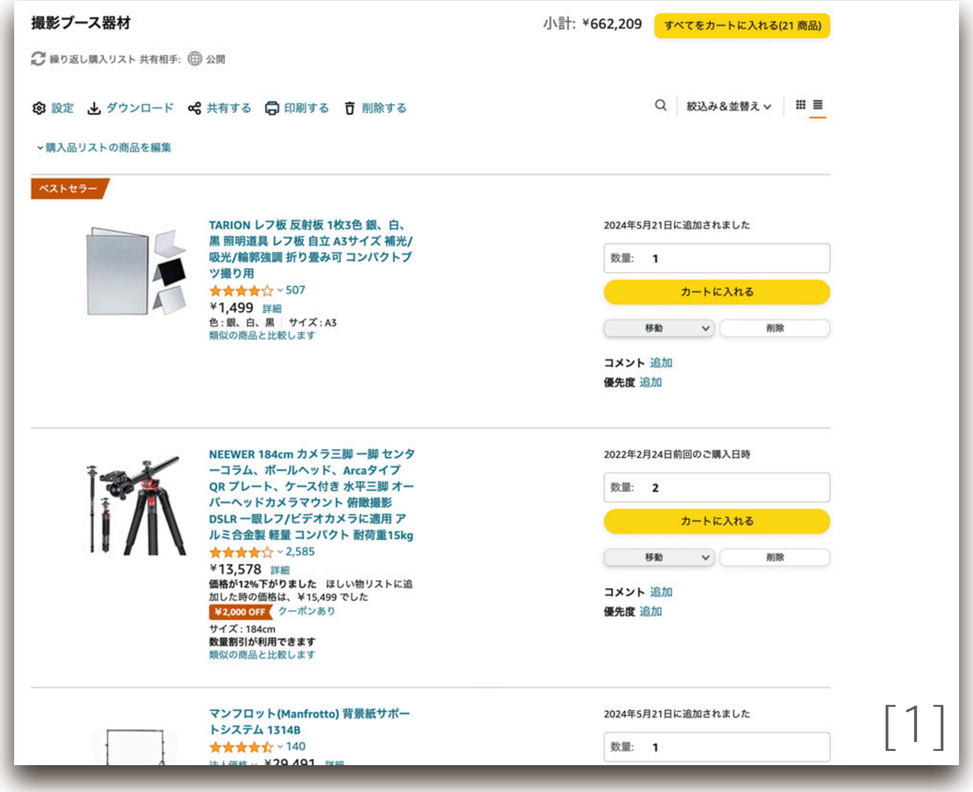
"Convenient" zoom lens [1]

A Macro lens [2]

I mostly use a **"convenient" zoom lens**, which is usually enough for papers.
Optionally a **macro lens** works better for specific shots.

[1] Sony SEL24105G, Amazon, [2] Sony SEL90M28G, Amazon

Other equipment



[1]

[2]

A list of our photo booth equipment: https://amzn.asia/4UCd0tm

WARNING: DO NOT ACCIDENTALLY BUY from our Amazon Wish List.

[1] Our photobooth equipment on Amazon Wish List. [2] Backpaper on 銀一

Today's topics

Video-shooting environment

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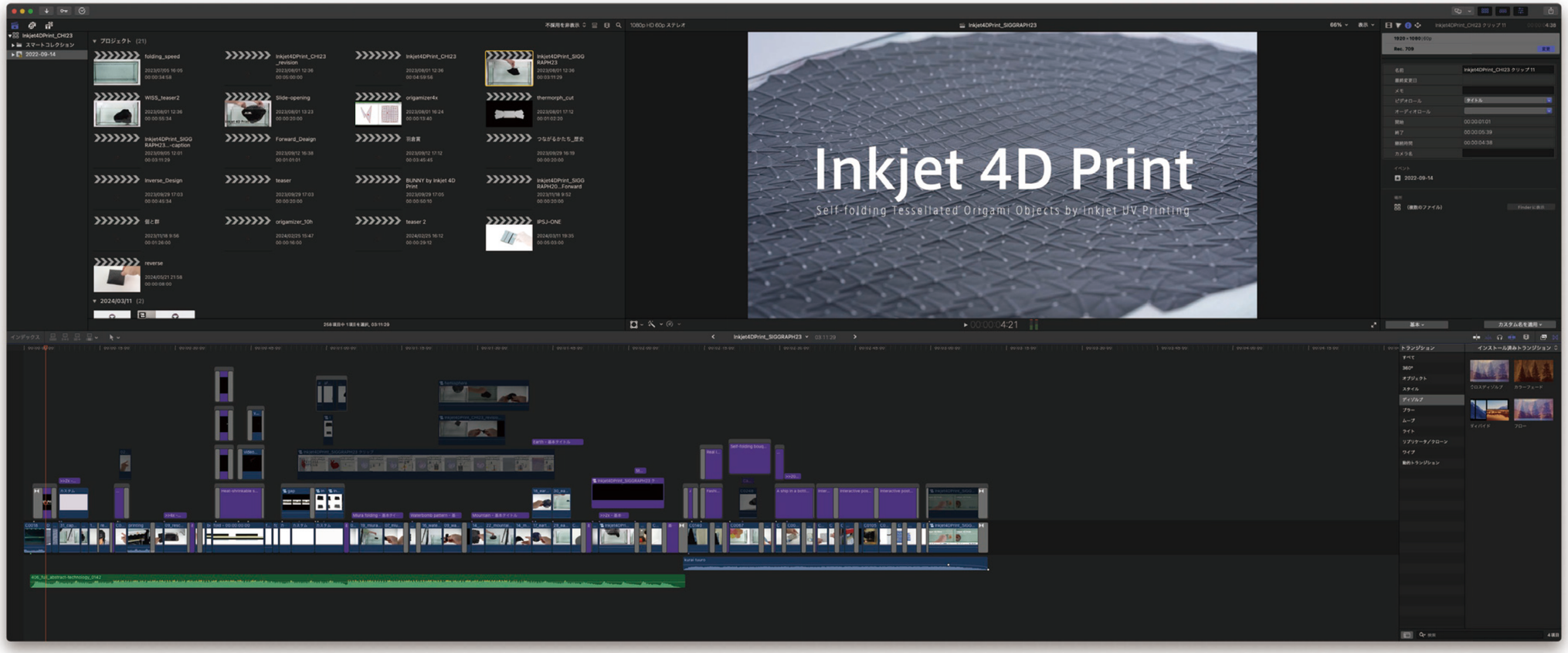
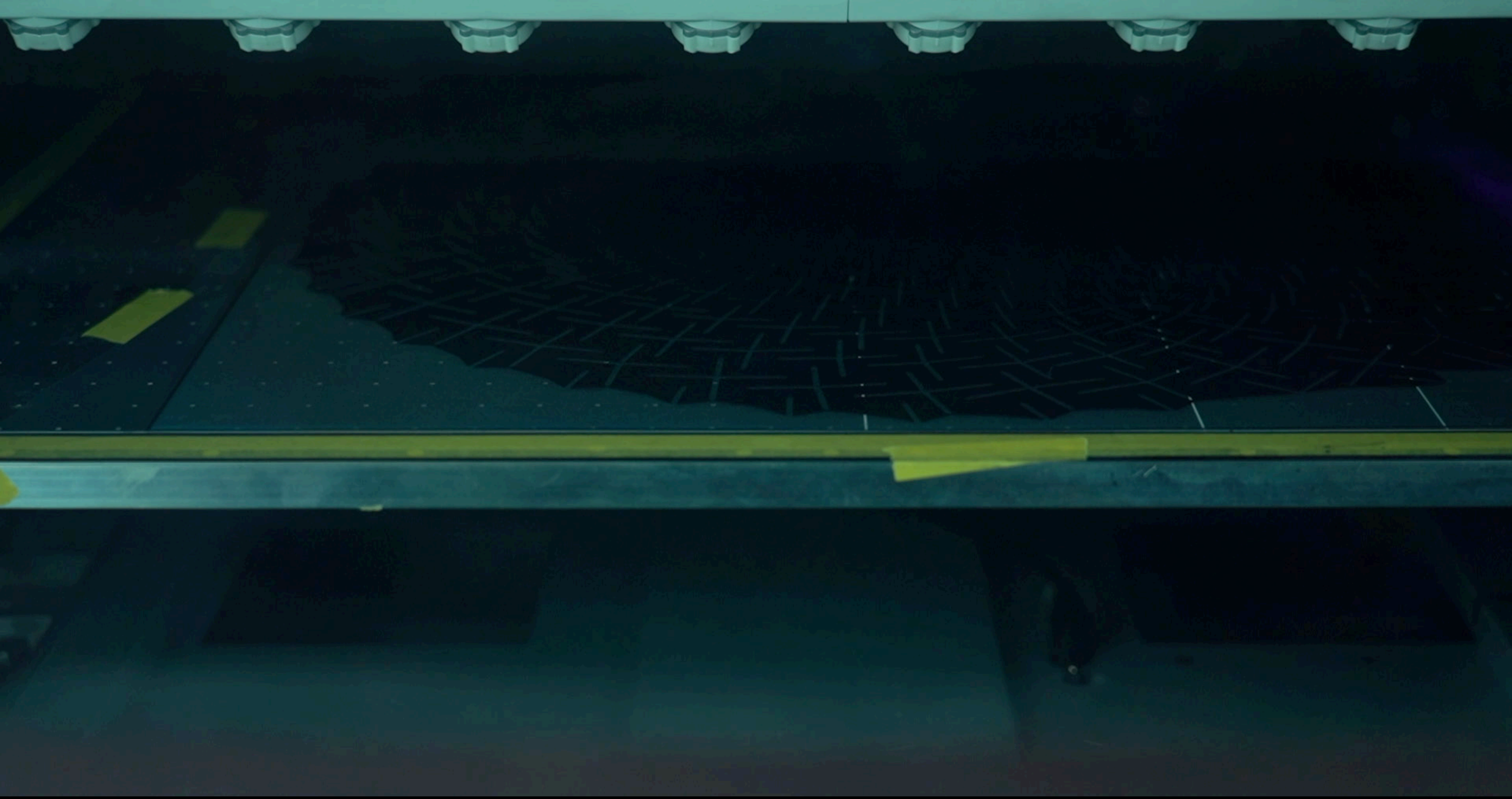
Let's check **other great videos**.

VIDEO EXAMPLES FROM MY VIDEOS

I often compose videos with Final Cut Pro

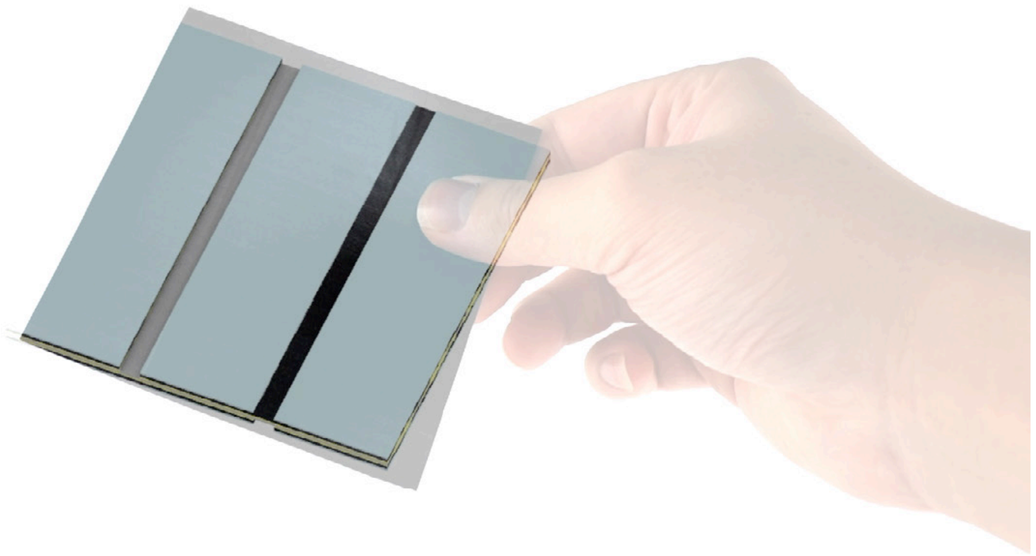


You can do similar things with **Premiere** or **DaVinci Resolve**.



Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

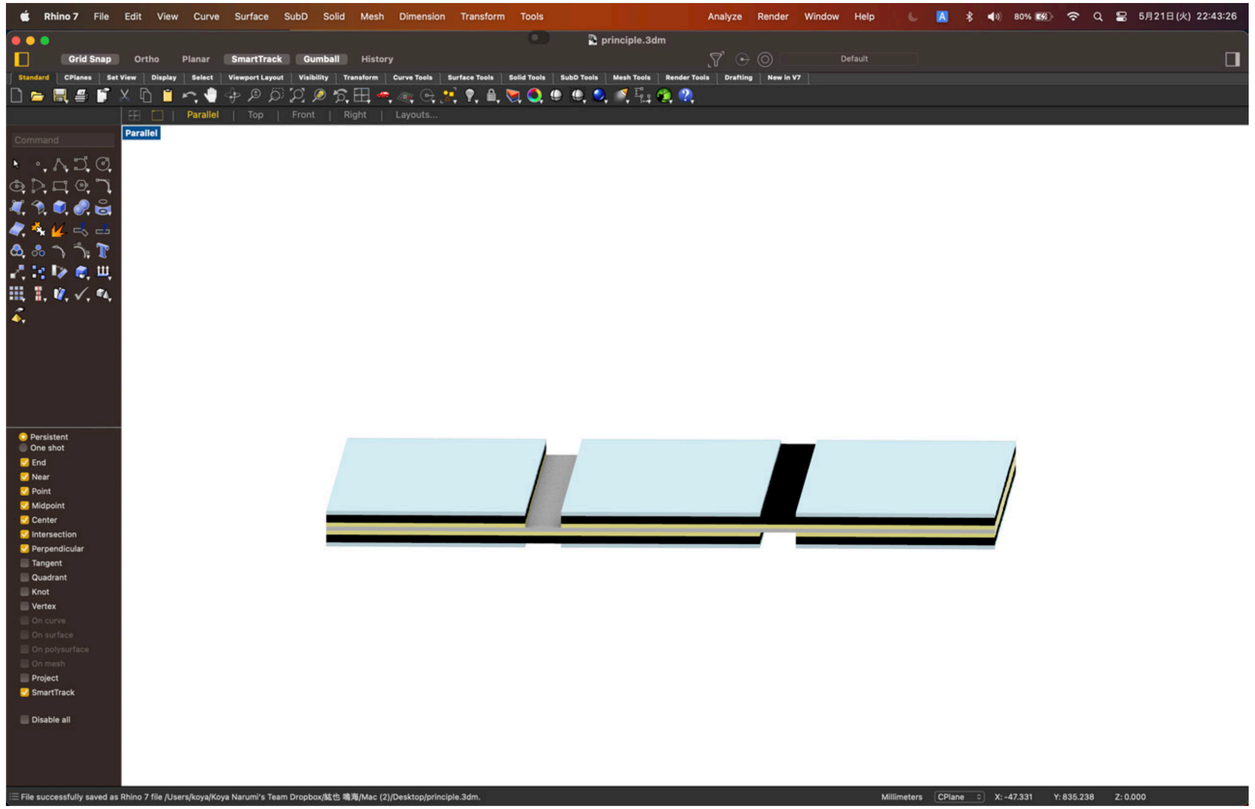
Example 1: Photo-schematic transition



How did I make this?

Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

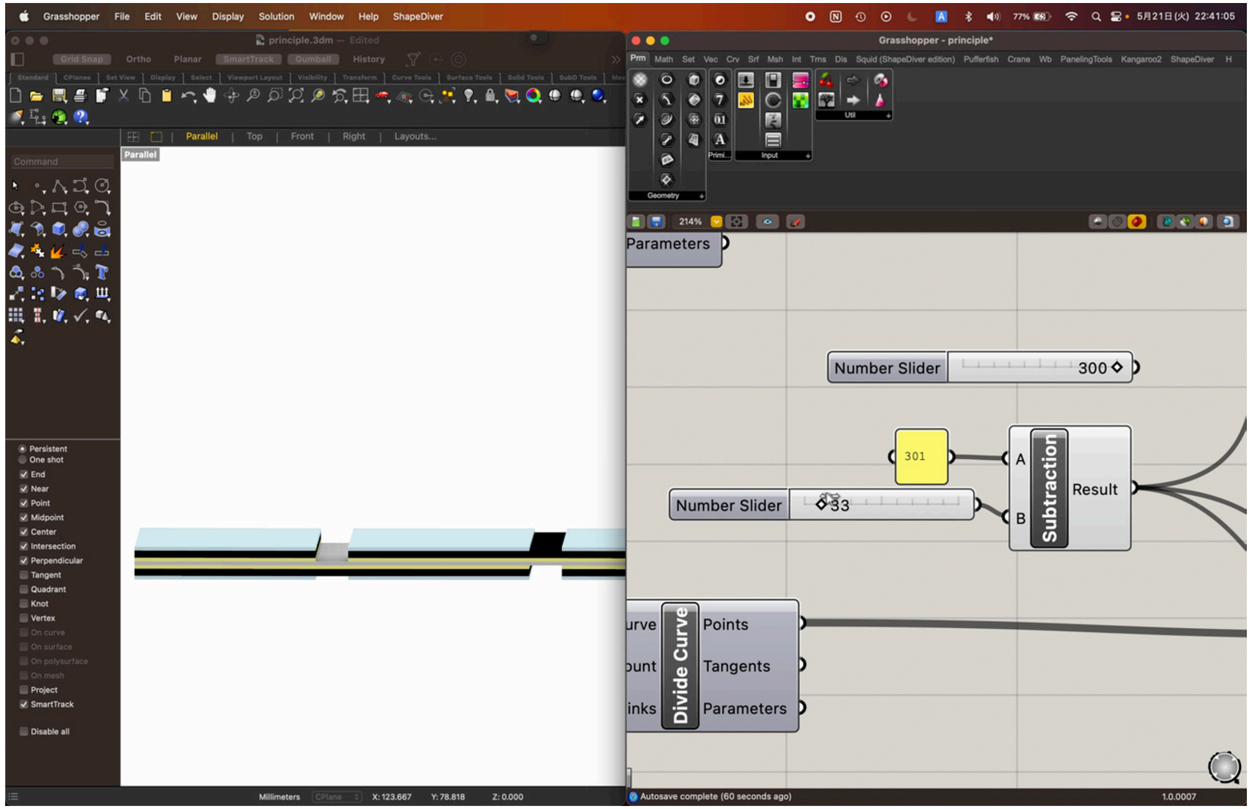
① Prepare a 3D model on Rhino/Grasshopper



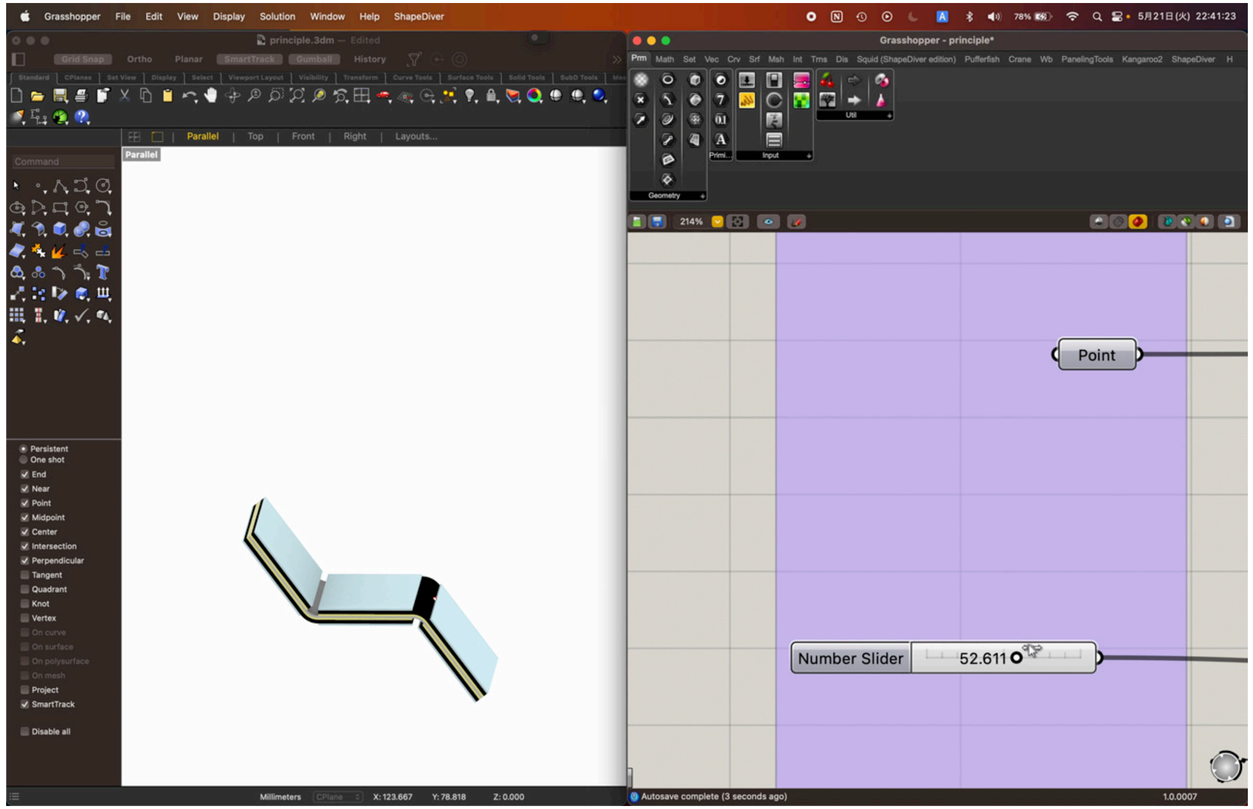
A 3D schematic made with **Grasshopper**.

Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

② Parametrically transform a camera and the shape



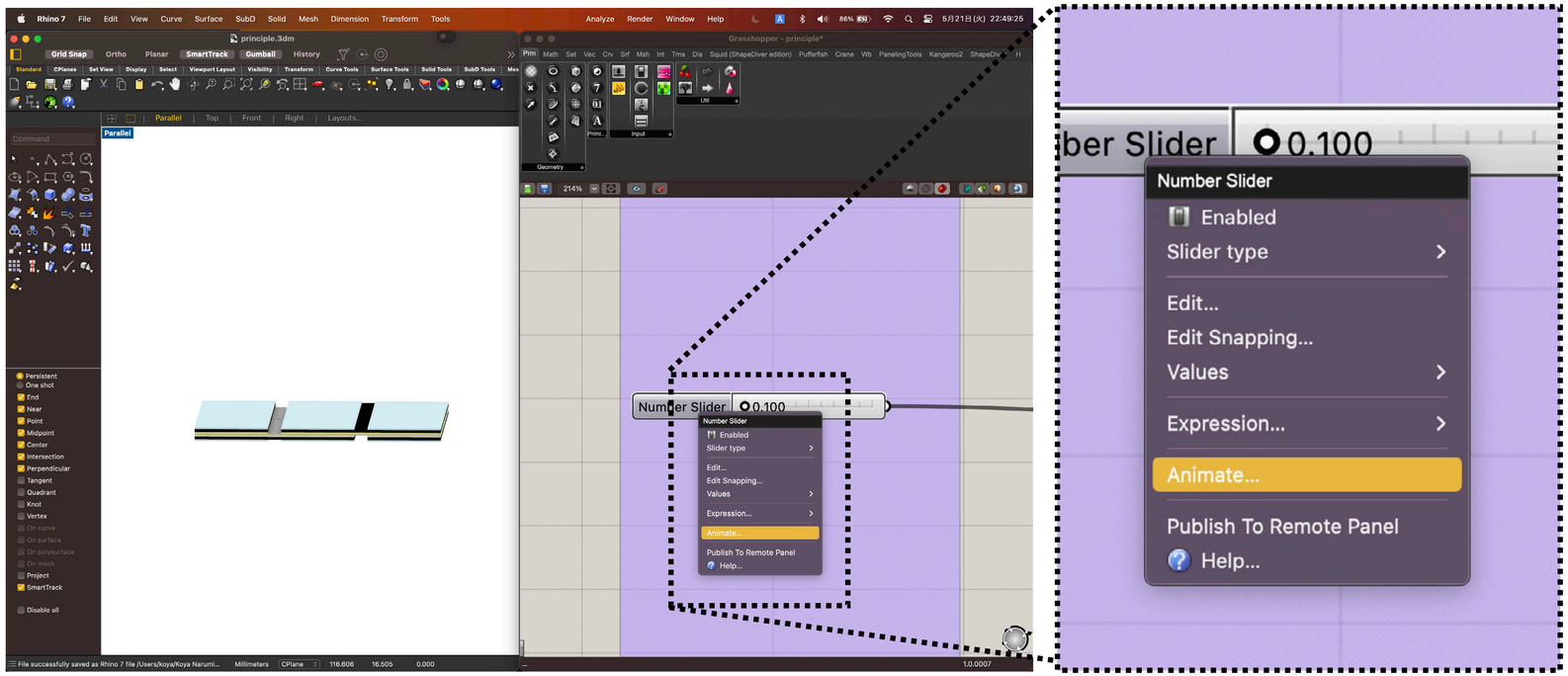
Parametrically moving a **camera position** (with a “Horster” plugin)



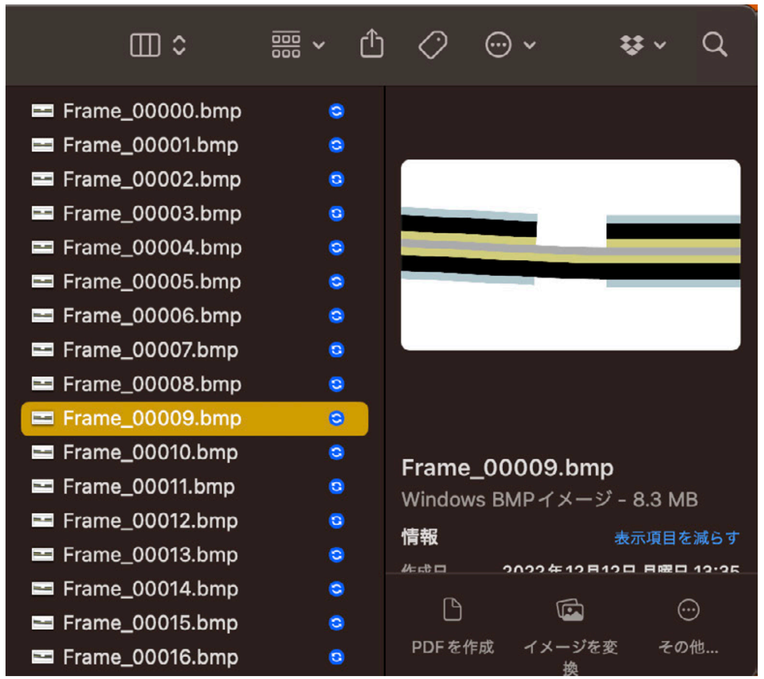
Parametrically moving the **shape**

Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

③ Record animation frames



Right click a number slider to "**Animate**"

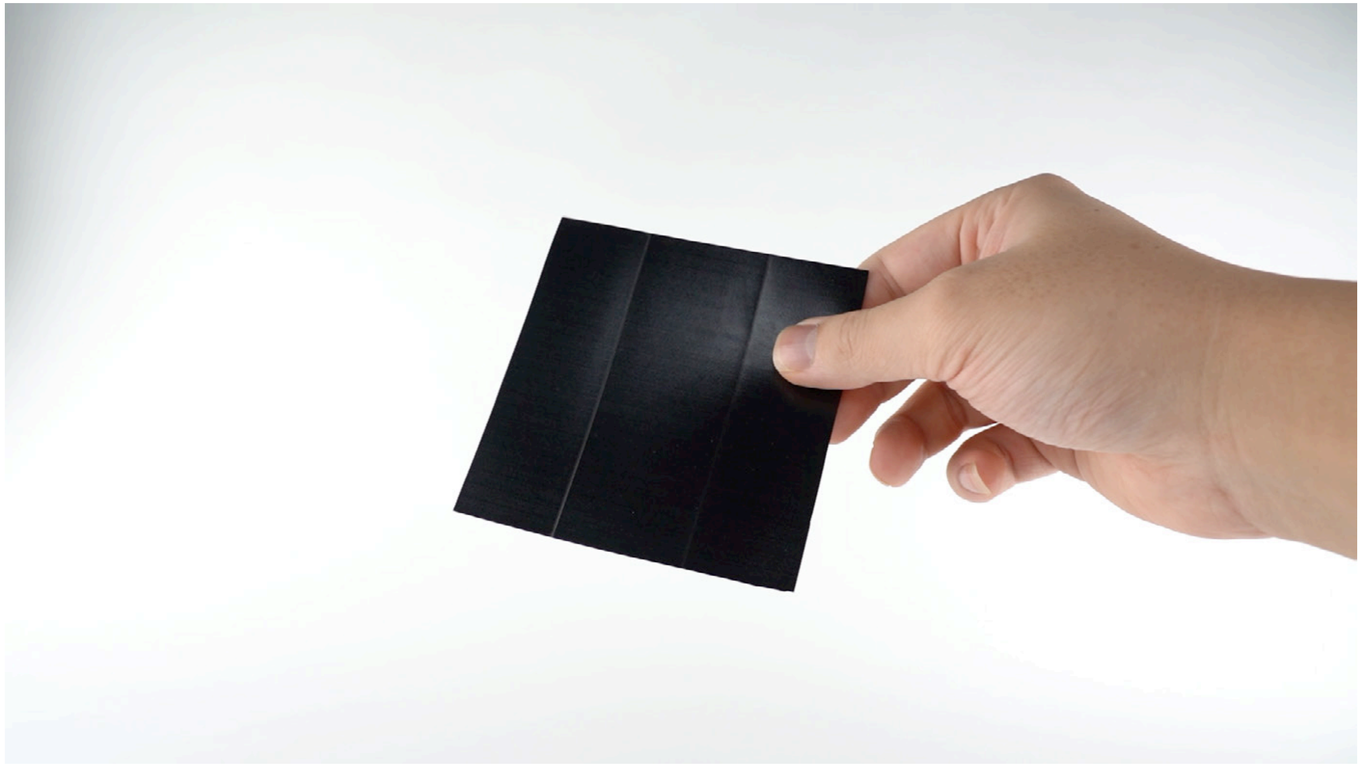


Generated animation frames

Grasshopper can generate **animation frames** by "animate."

Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

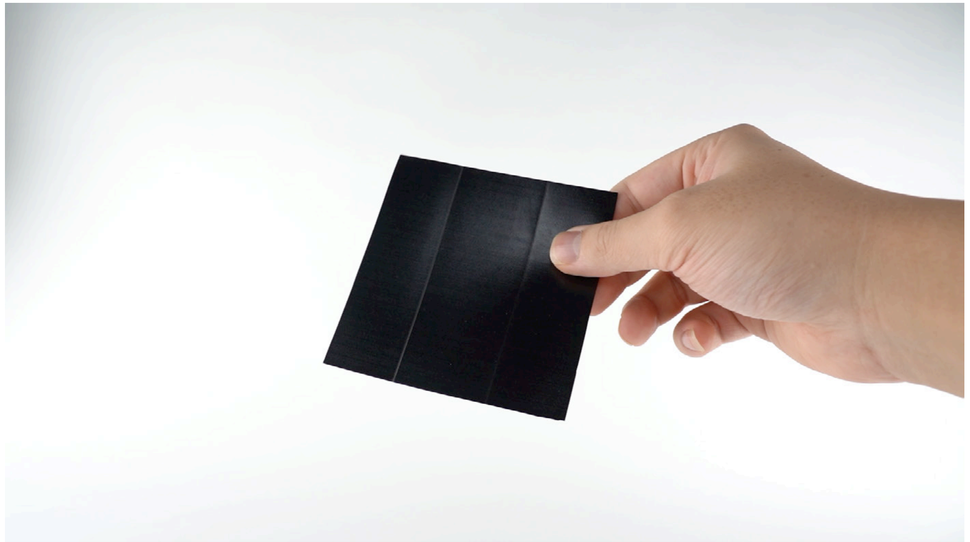
④ Take a movie at a similar angle



This doesn't have to be a movie, but I use a movie to find a suitable distance.

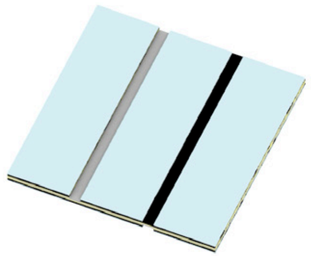
Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

⑤ Cross dissolve transition on Final Cut Pro



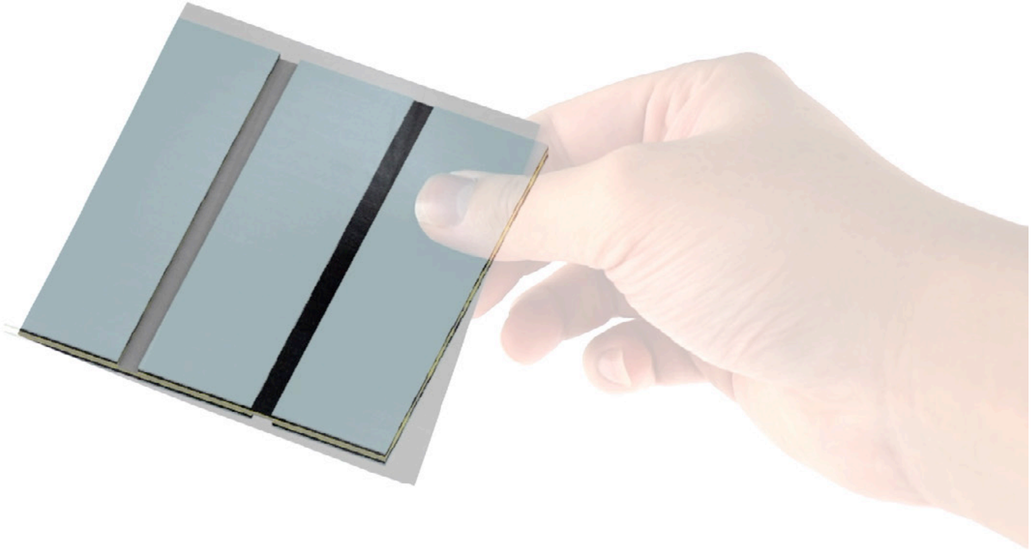
→

Cross dissolve transition



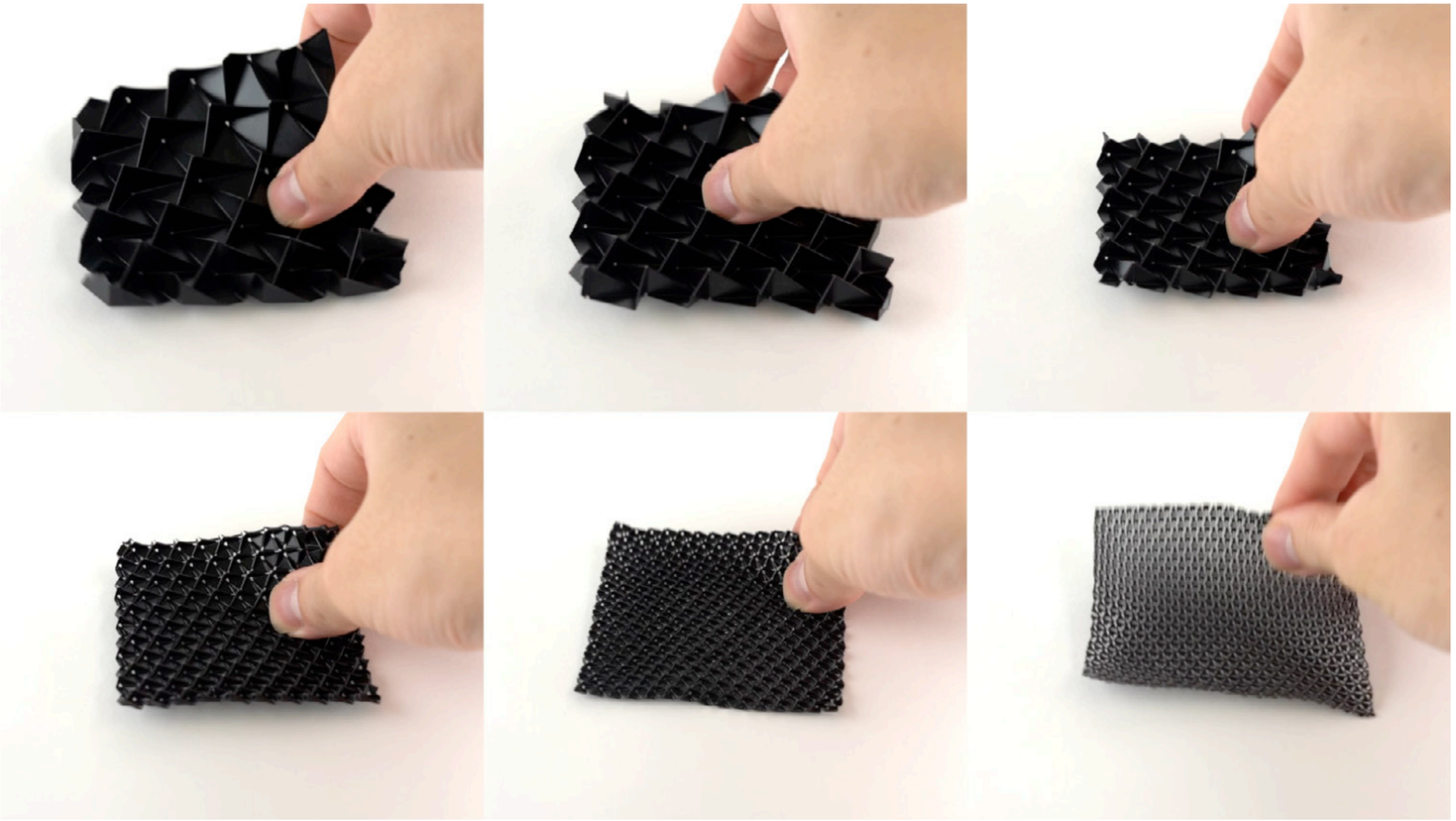
Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

Done



Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

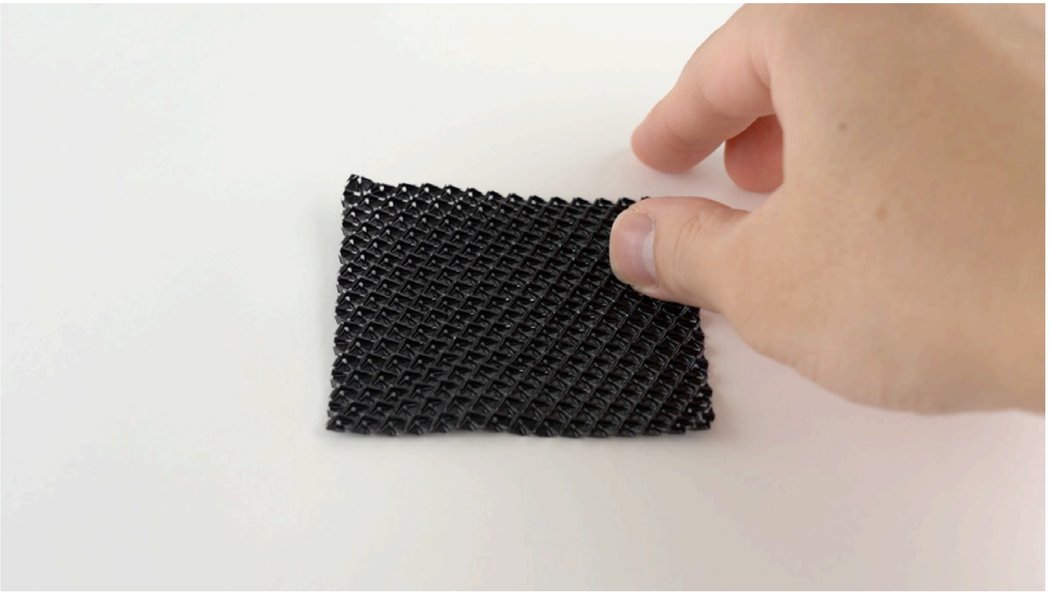
Example 2: Closed-up transition



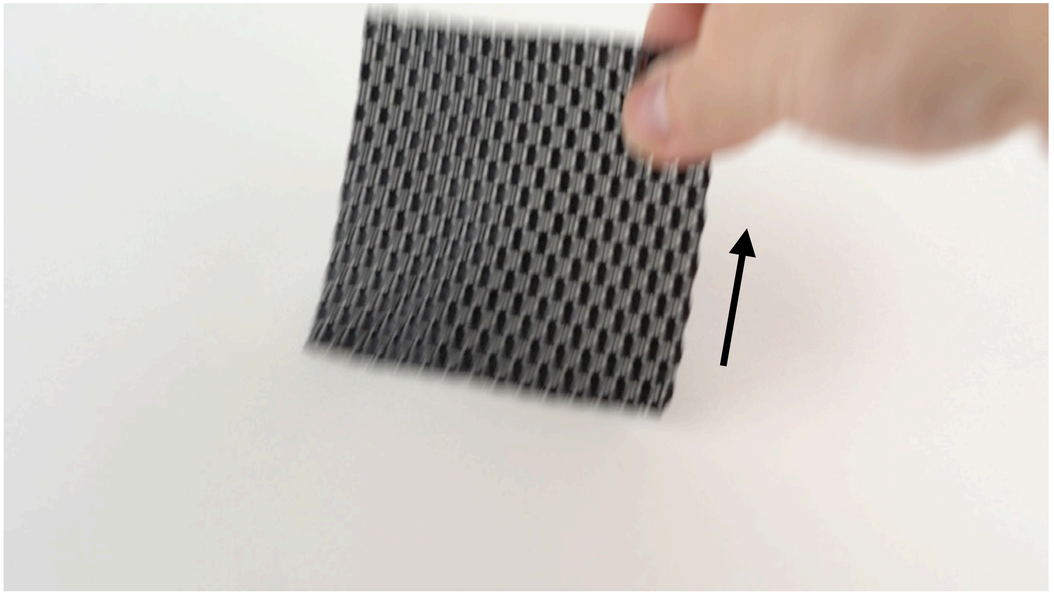
How did I make this?

Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

① Take a clip in a **REVERSED** order



Start by a placed sheet



Pick it up

It was very hard to precisely put a sheet at the center of the video frame.
Thus I took a movie **inversely**.

Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

① Take a clip in a **REVERSED** order

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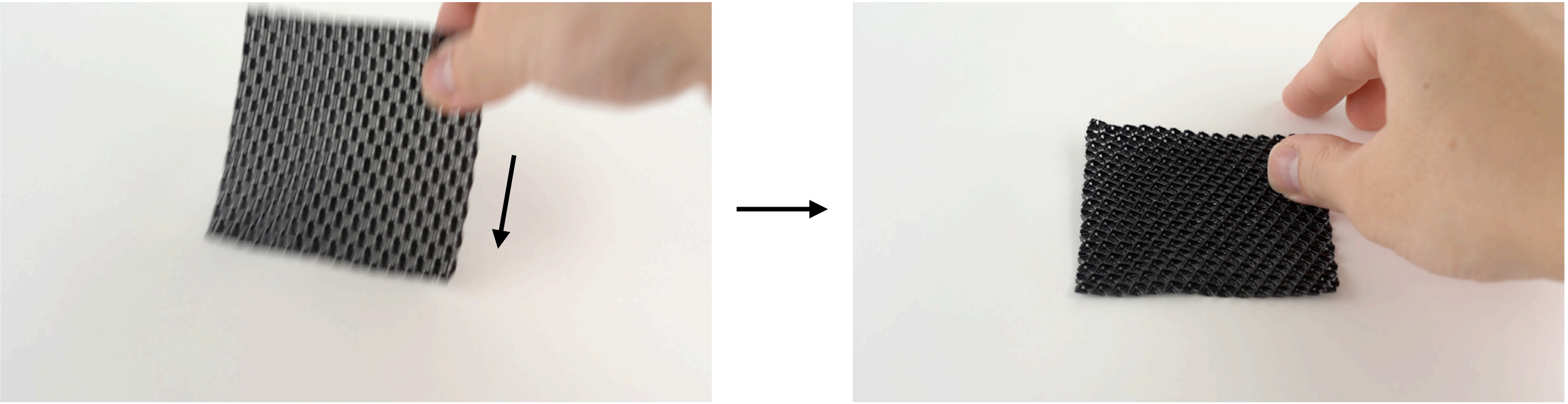
Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

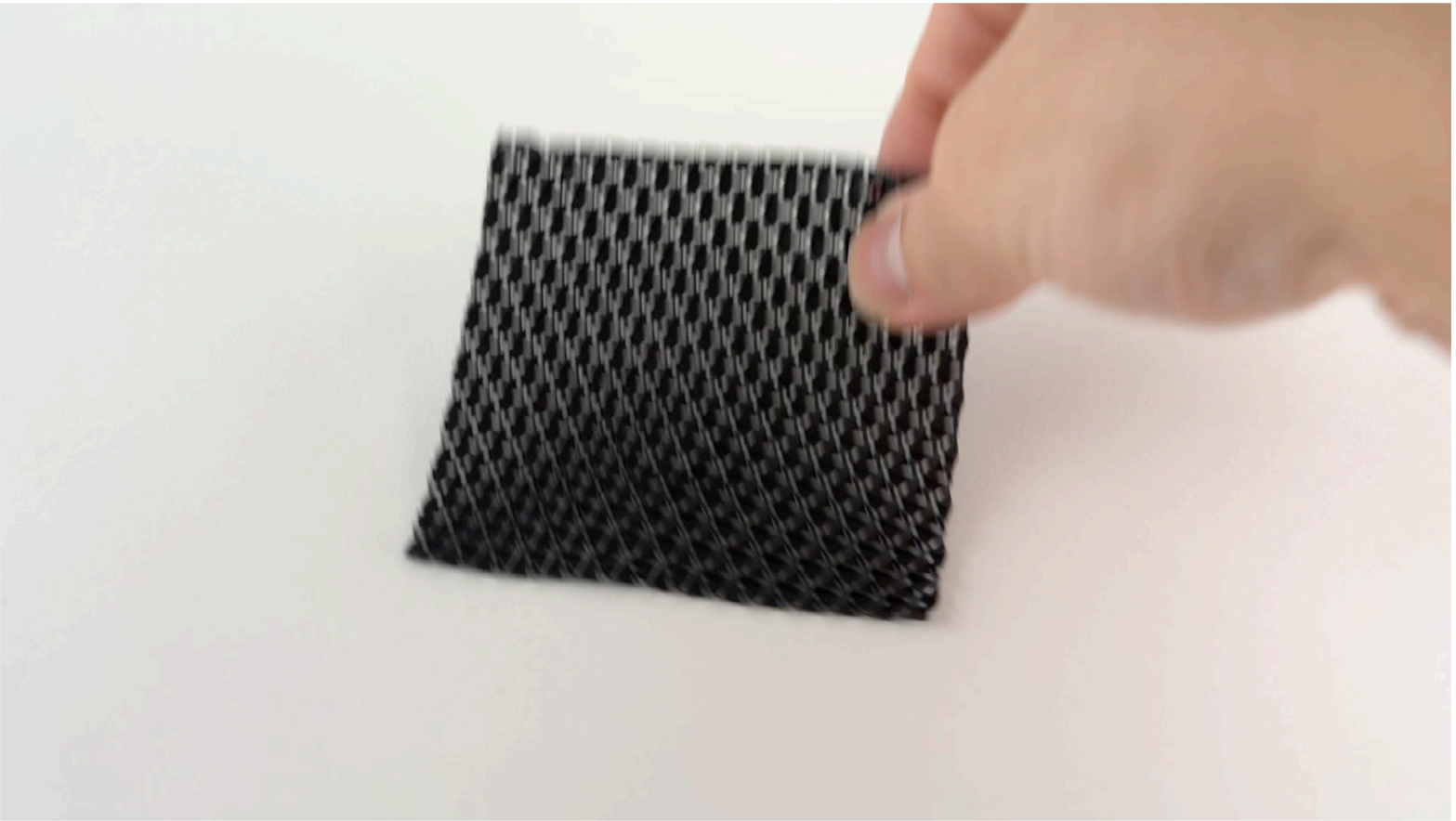
② Reverse-edit the clip



The reversed video is **as if** I placed a sheet on a table.

Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

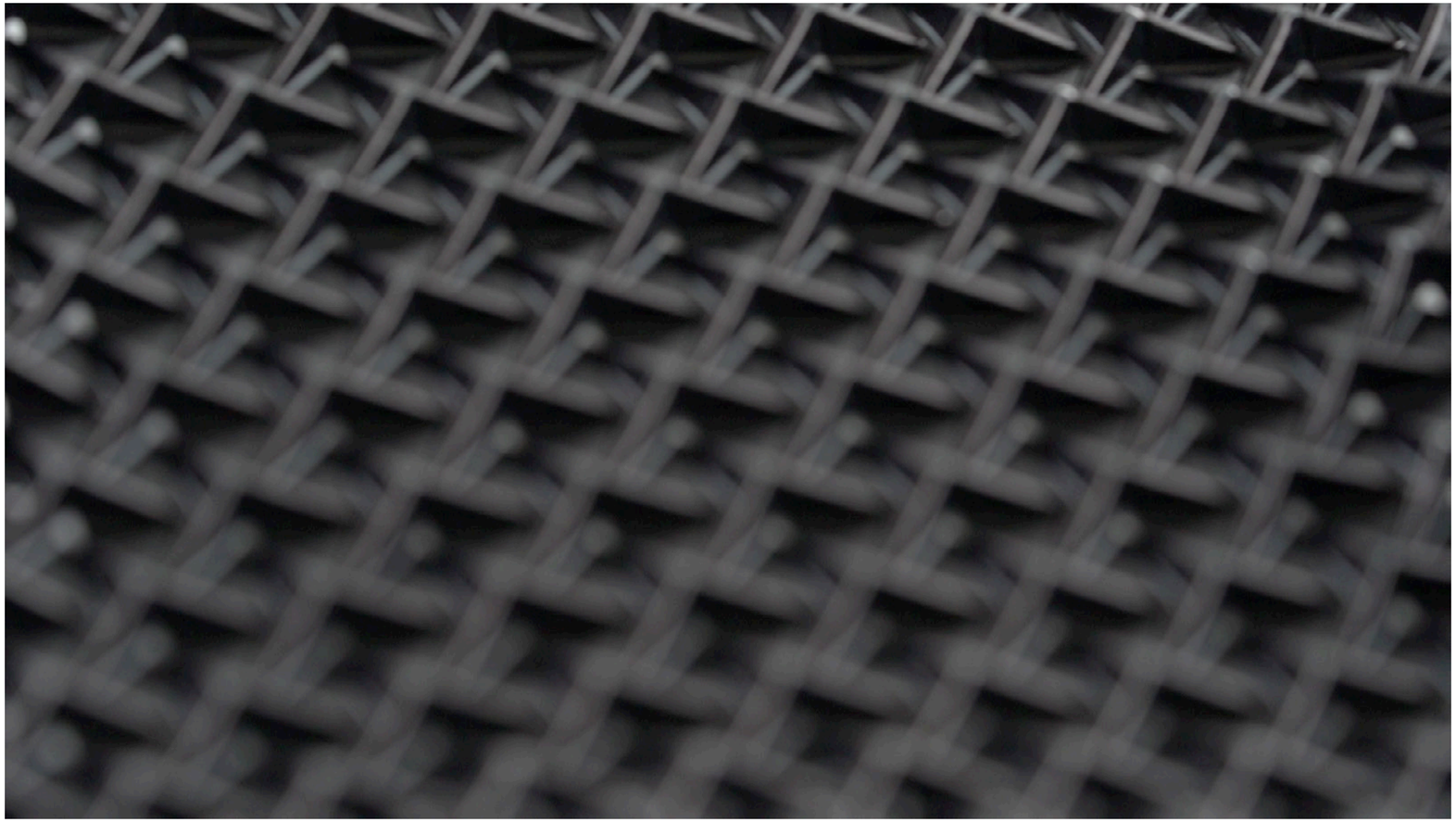
② Reverse-edit the clip



The reversed video is **as if** I placed a sheet on a table.

Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

③ Take a closed-up clip

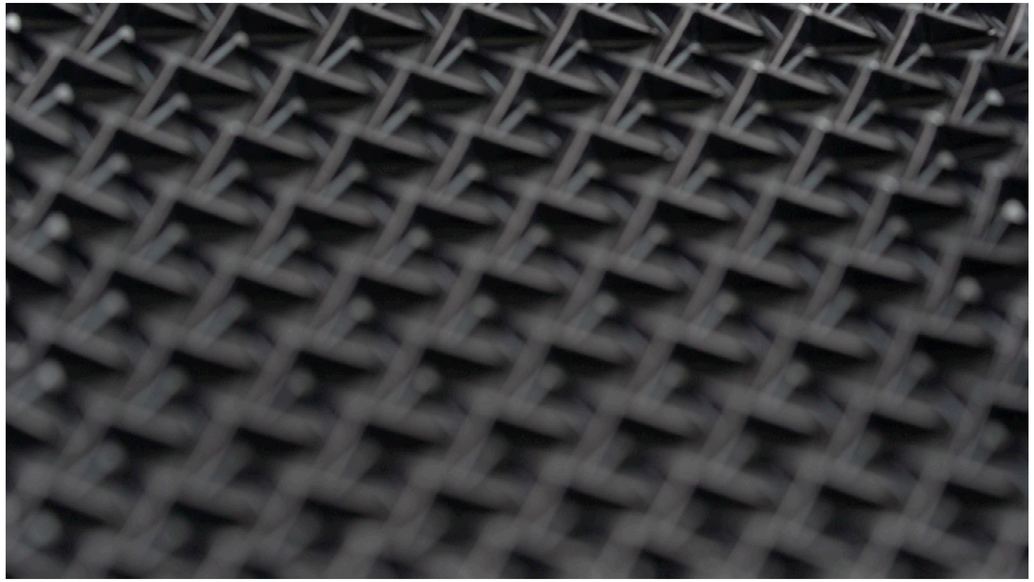


I **imitated a zooming effect** by de-focasing a macro lens.

Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

④ Zoom transition on Final Cut Pro

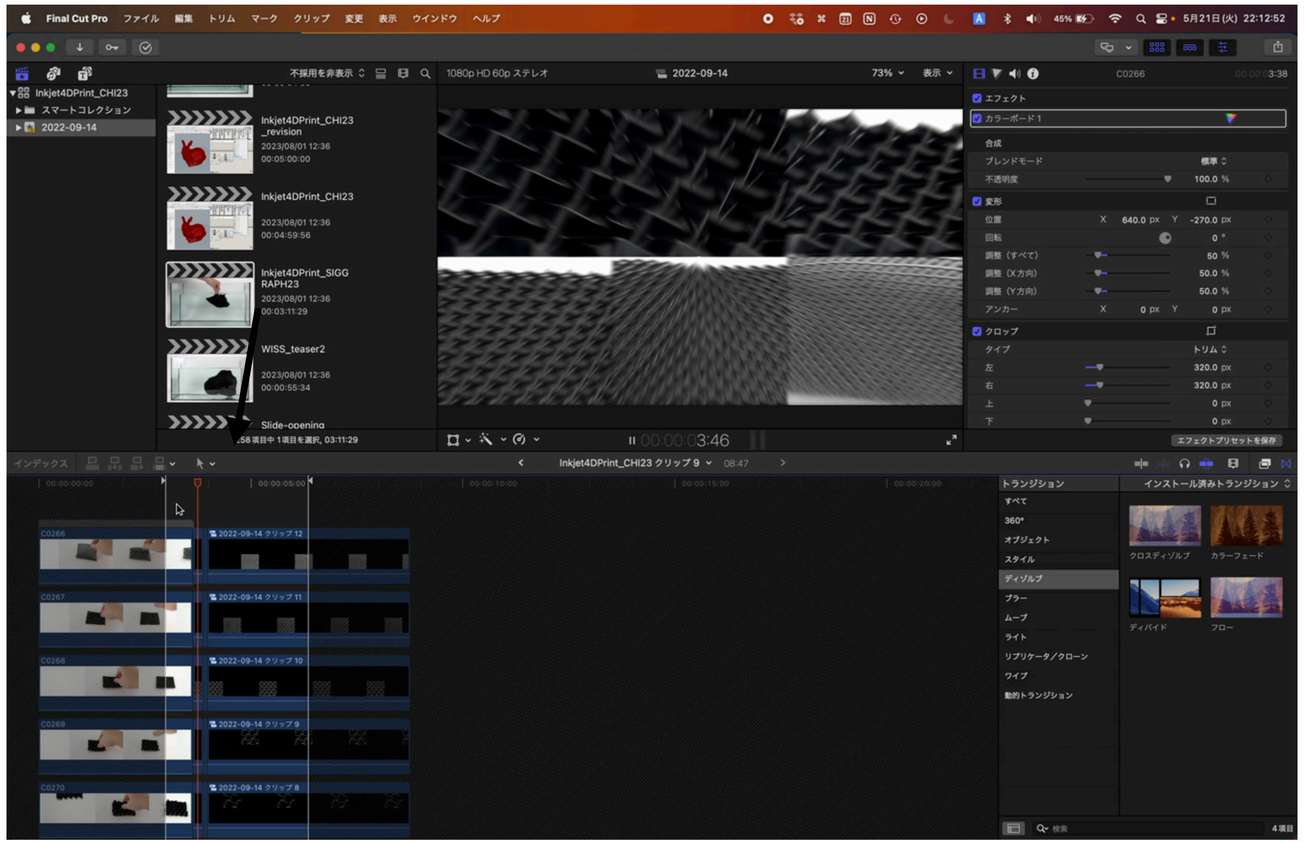
Zoom
transition



Connect two clips by **a zoom transition** effect.

Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

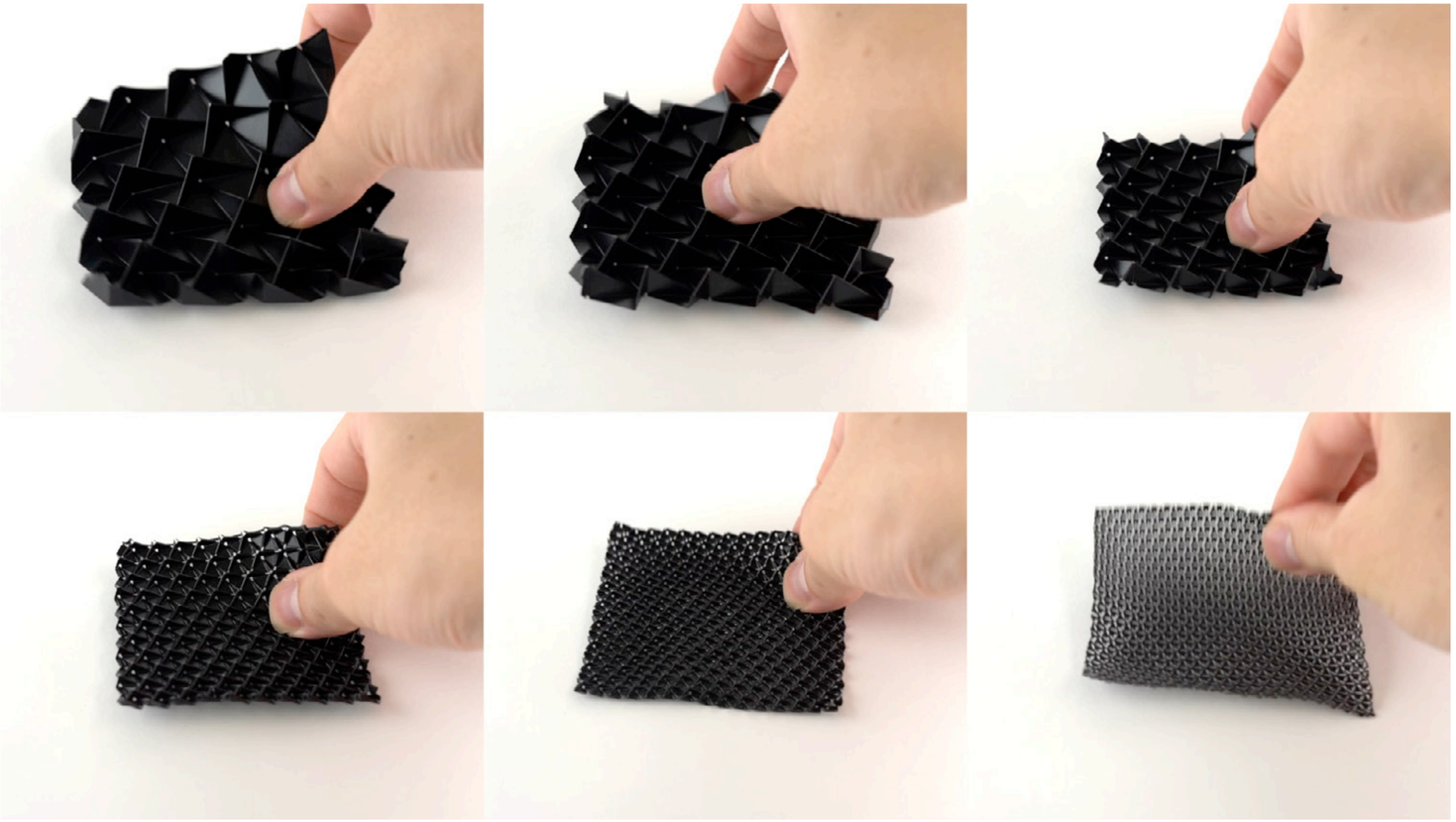
④ Zoom transition on Final Cut Pro



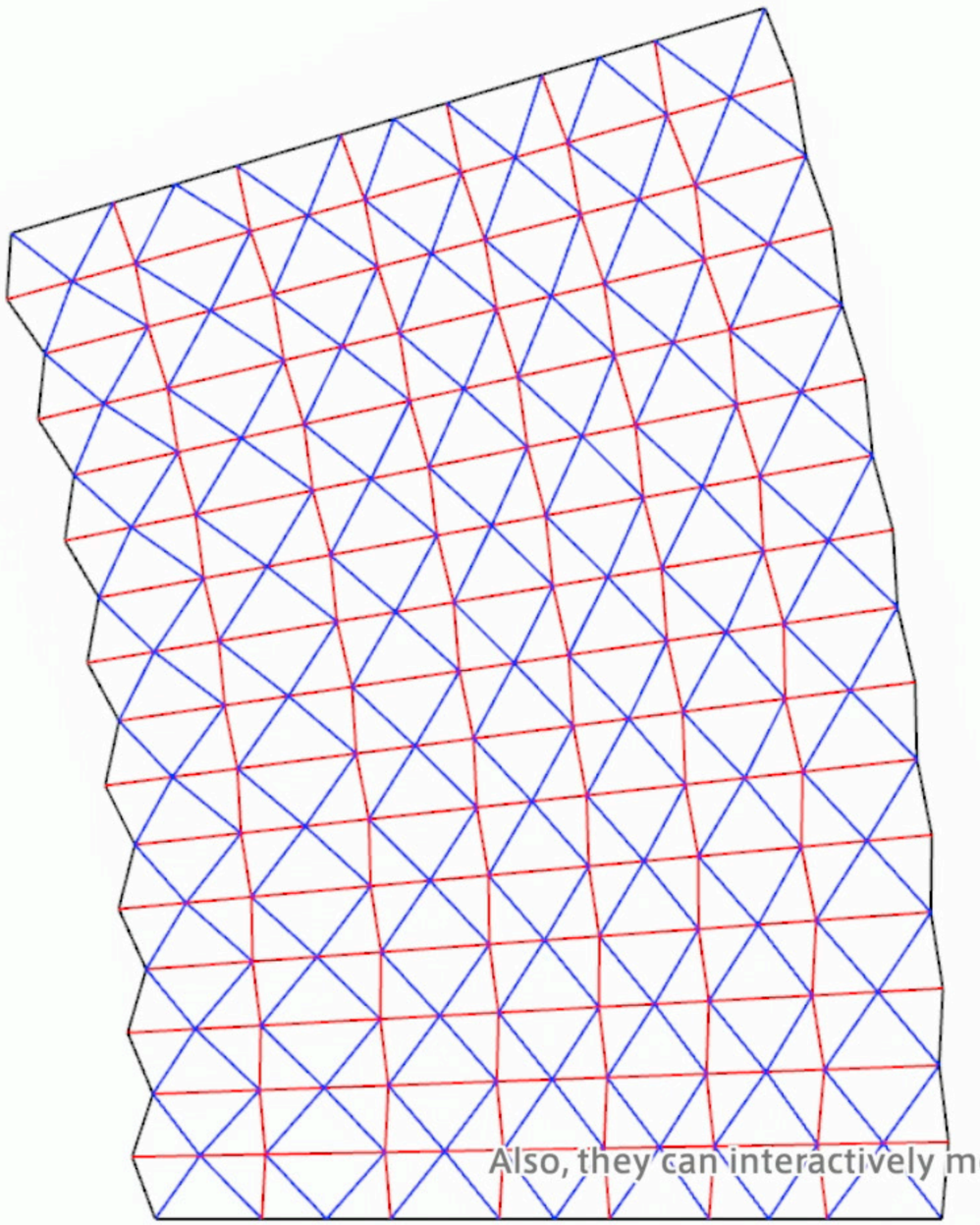
Connect two clips by **a zoom transition** effect.

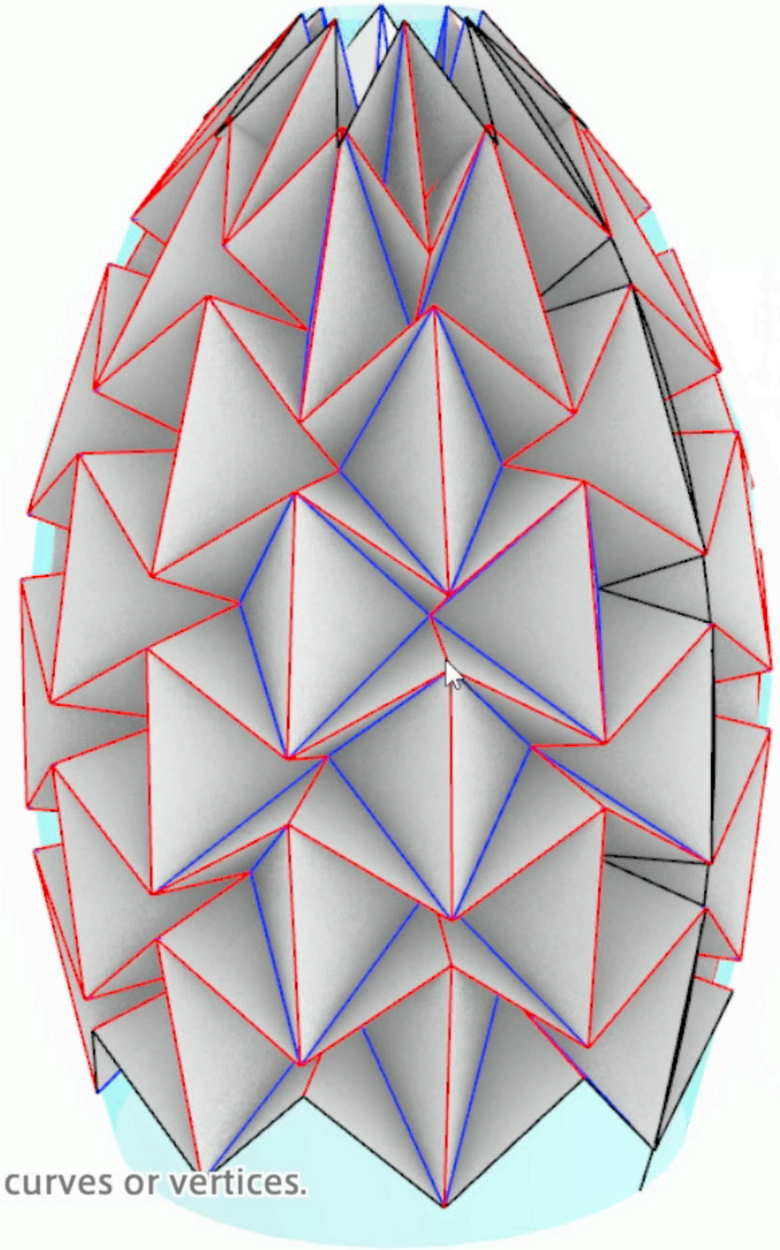
Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4

Done



Narumi & Koyama et al., Inkjet 4D Print, TOG, 2023. https://youtu.be/2rY-XNBnTW4





Also, they can interactively modify the shape by grabbing curves or vertices.

Suto et al., Crane, TOCHI 2023. https://youtu.be/1HRlDPuNSMo

Example 3: Color grading

Slightly dyed color **only for the assembly process**

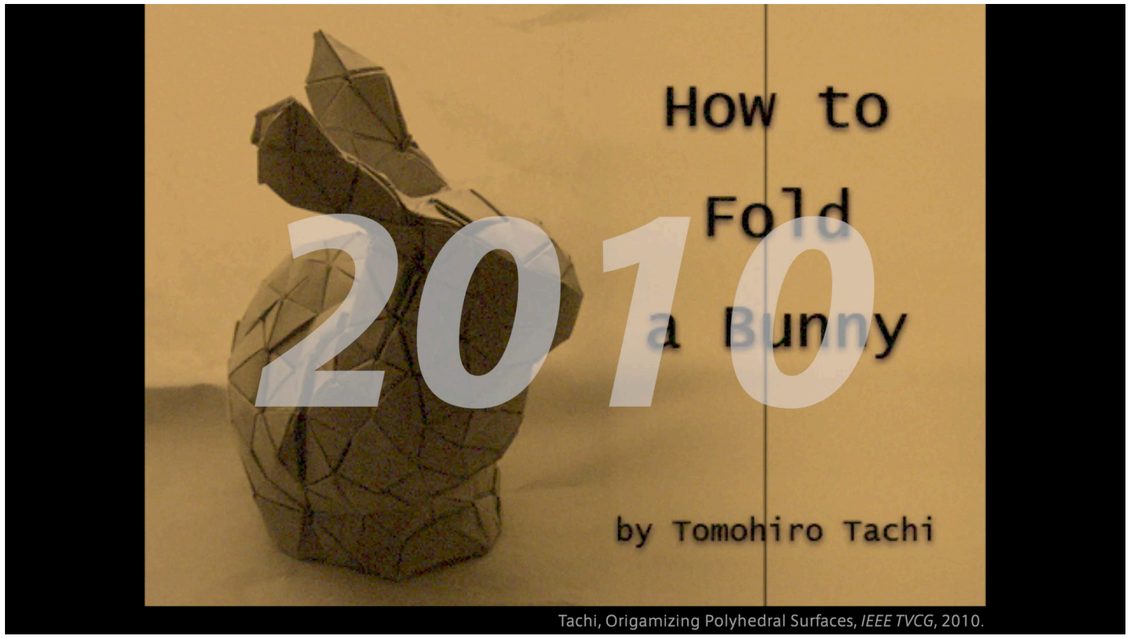
Sometimes **color grading** is effective to tell differences.

Suto et al., Crane, TOCHI 2023. https://youtu.be/1HRlDPuNSMo

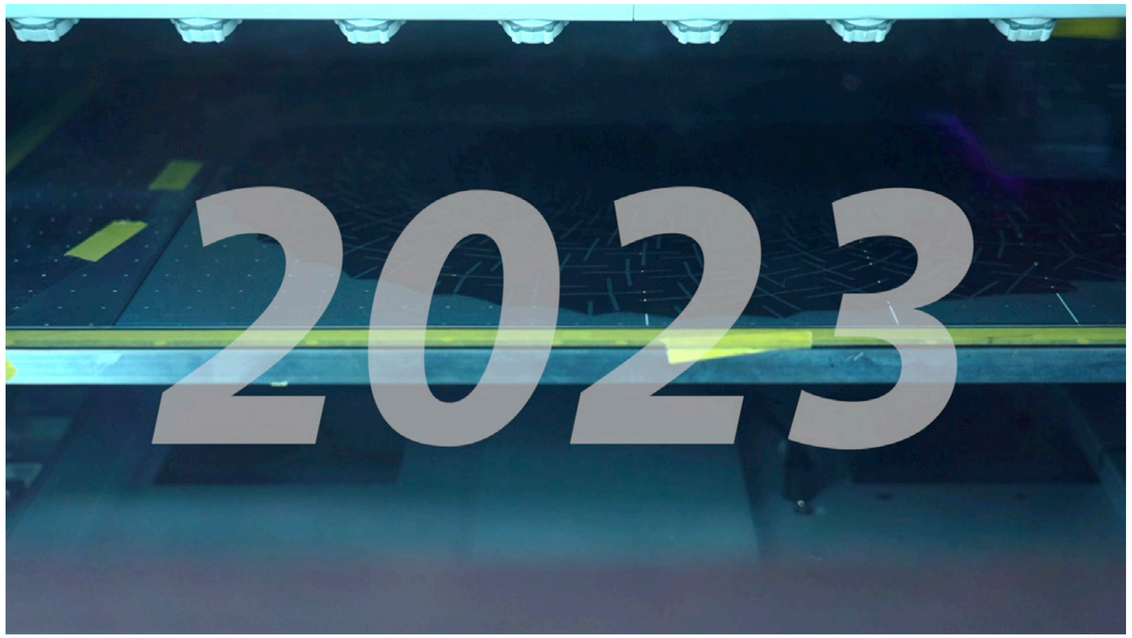
2010

Narumi & Koyama et al., Inkjet 4D Print, TOG 2023.

Example 3: Color grading



Red color grading **for the past**



Blue color grading **for now**

Sometimes **color grading** is effective to tell differences.

Narumi & Koyama et al., Inkjet 4D Print, TOG 2023.

Narumi & Qin et al., Self-healing UI, UIST 2018. https://youtu.be/kpmmUsjgOPg

Example 4: Time-lapse

Raw video

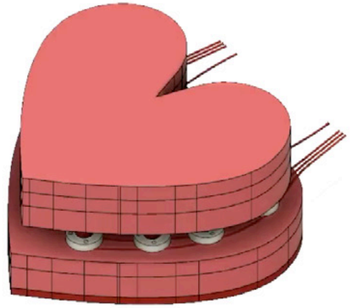
Edited video

I took approx. 1700 **time-lapse photos** for the 6-hour self-folding process.

Narumi & Qin et al., Self-healing UI, UIST 2018. https://youtu.be/kpmmUsjgOPg

Example 5: Layer animation

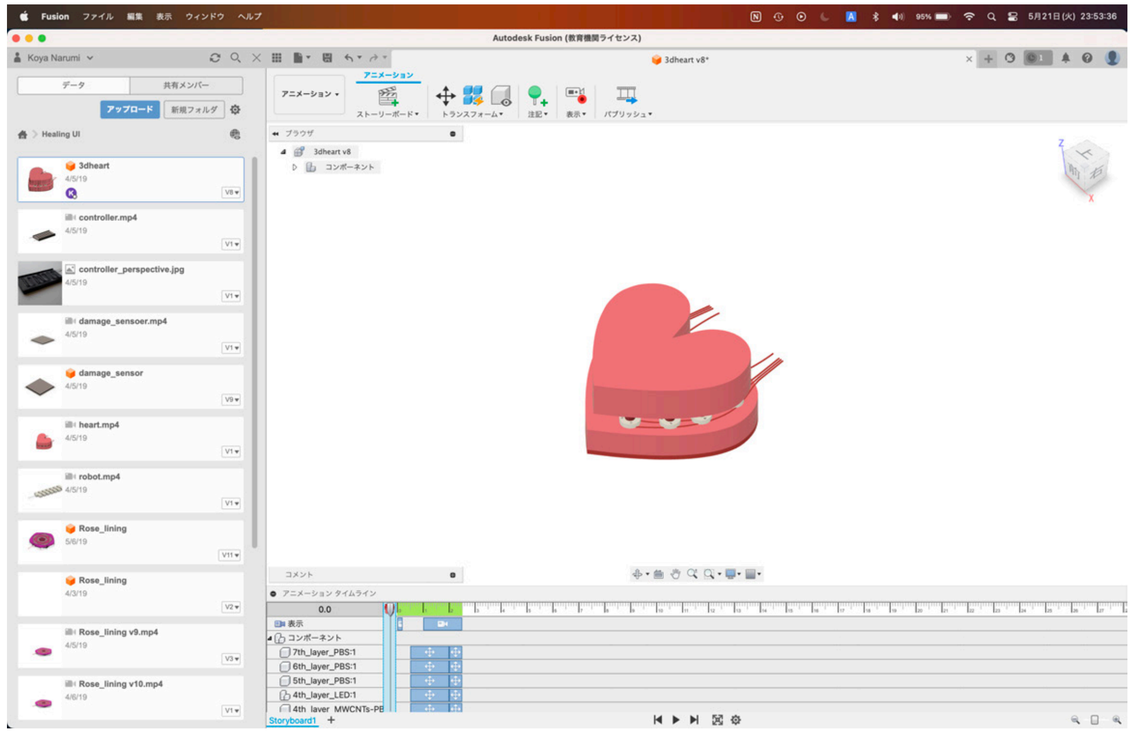
Healing heart



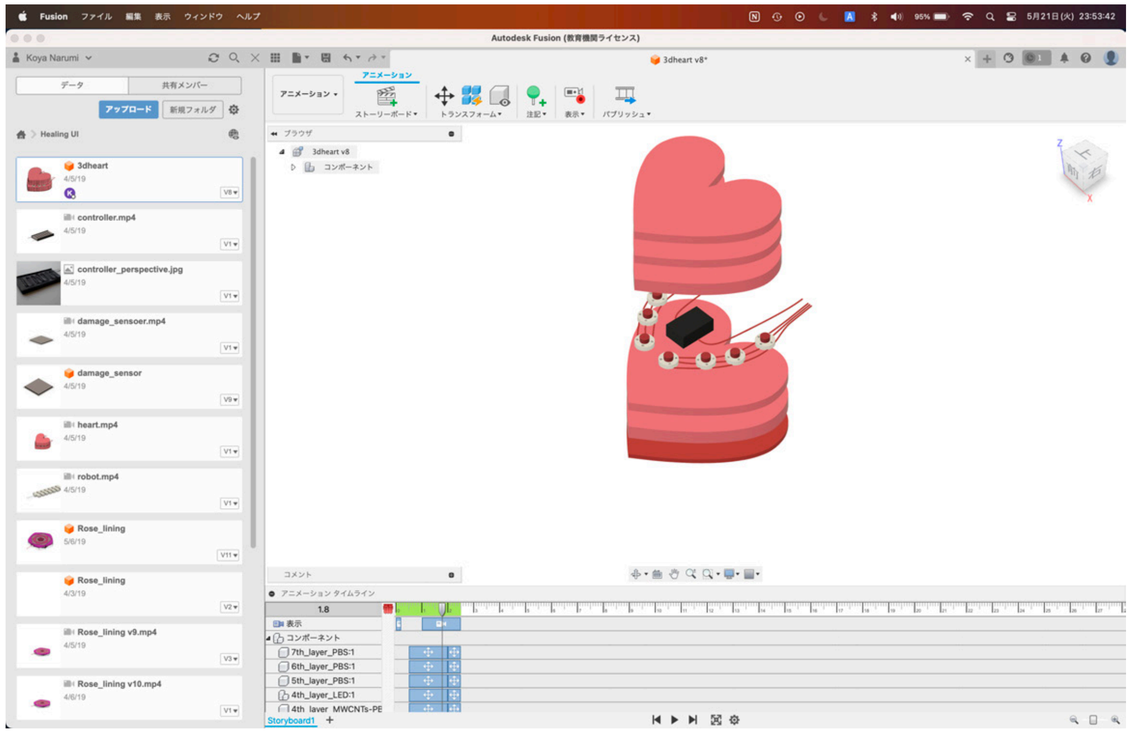
Fusion 360 has a animation function as a default.

Narumi & Qin et al., Self-healing UI, UIST 2018. https://youtu.be/kpmmUsjgOPg

Example 5: Layer animation



Before

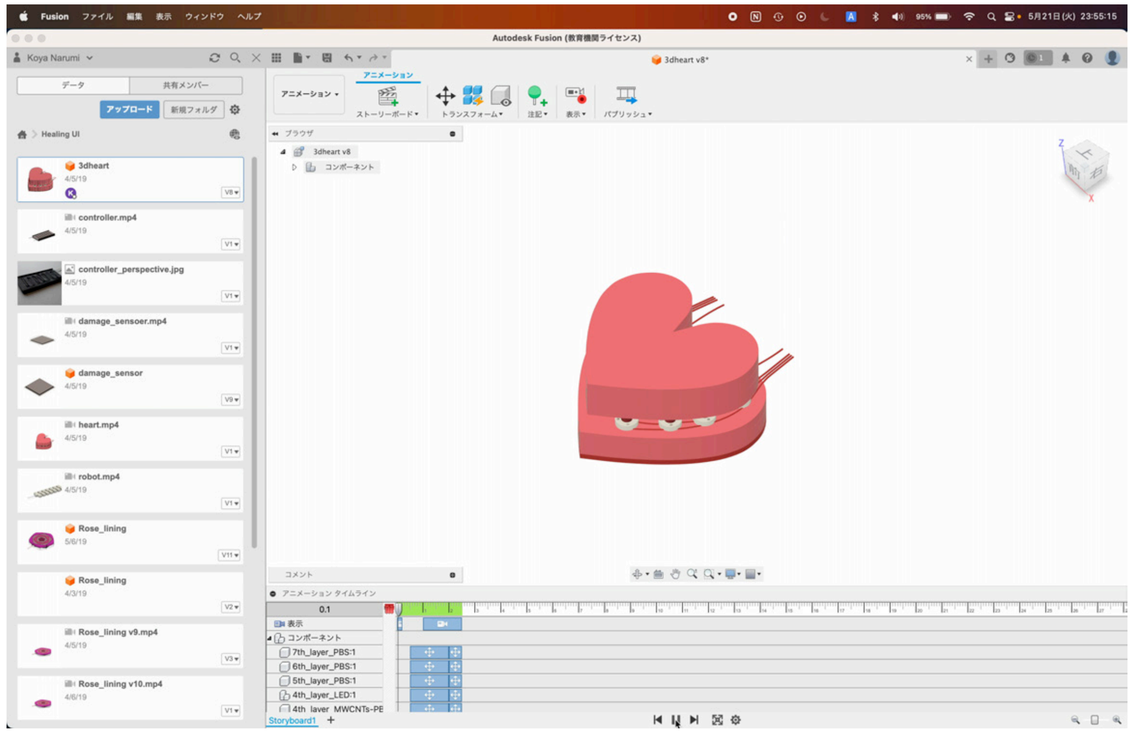


After

Fusion 360 has a function of animation as a default.

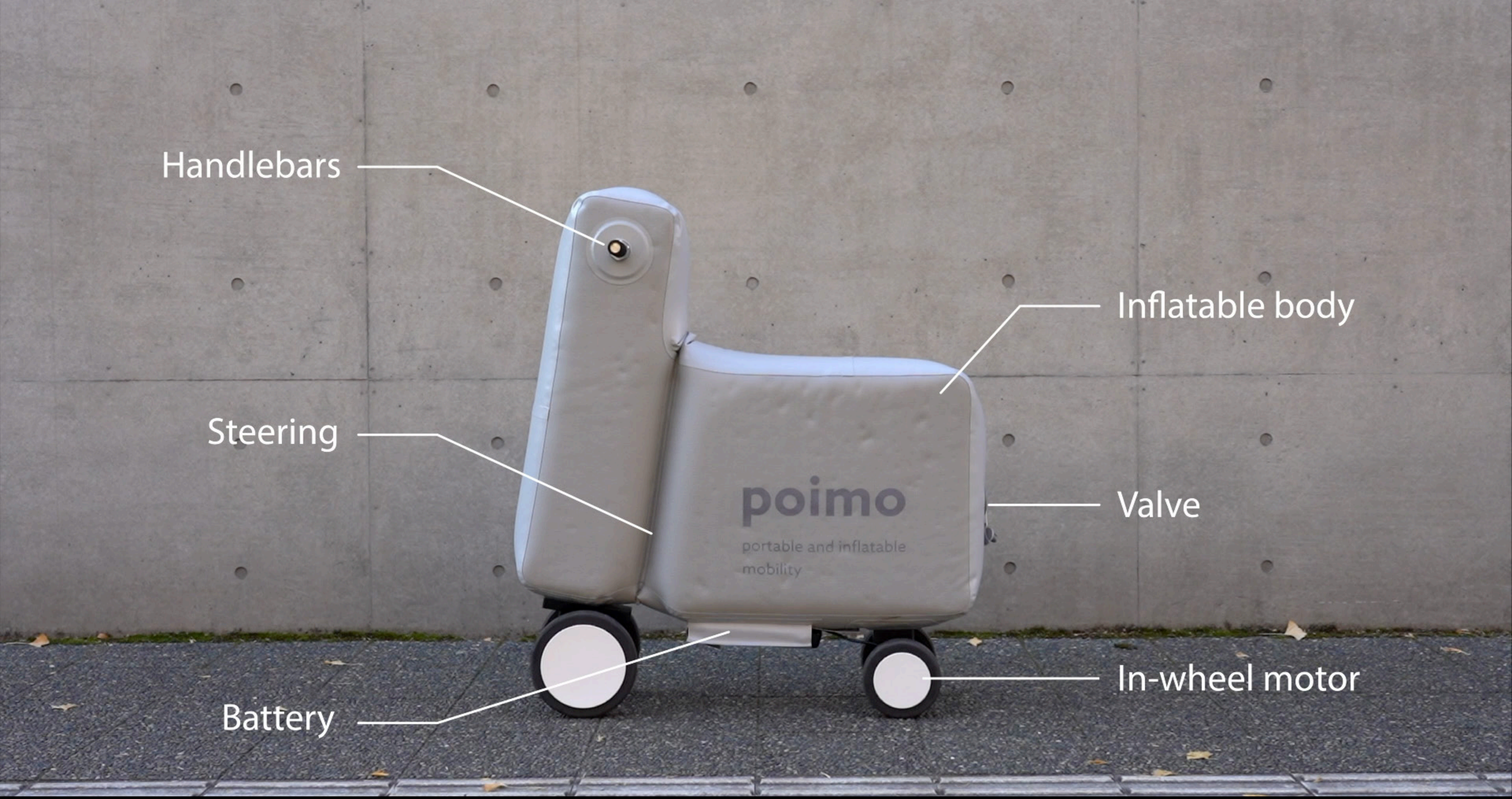
Narumi & Qin et al., Self-healing UI, UIST 2018. https://youtu.be/kpmmUsjgOPg

Example 5: Layer animation



Fusion 360 has a function of animation as a default.

Narumi & Qin et al., Self-healing UI, UIST 2018. https://youtu.be/kpmmUsjgOPg



Niiyama et al., Soft yet Strong Inflatable Structures, CHI 2019 EA. https://youtu.be/0F-B-xAxwog

Example 6: a gimbal shot

A **gimbal** is useful for a dynamic chasing shot.

Niiyama et al., Soft yet Strong Inflatable Structures, CHI 2019 EA. https://youtu.be/0F-B-xAxwog

Example 6: a gimbal shot

DJI OSMO Mobile

DJI OSMO Pocket

DJI Ronin

A **gimbal** is useful for a dynamic chasing shot.

Photos cited from https://www.dji.com/

Today's topics

Video-shooting environment

I like to take videos **in the same environment as photos**.

Video examples from my videos

Six video tips from my past videos.

Other video examples

Let's check **other great videos**.

OTHER
VIDEO EXAMPLES

Put-that-there

Voice and gesture input interfaces to put that there.

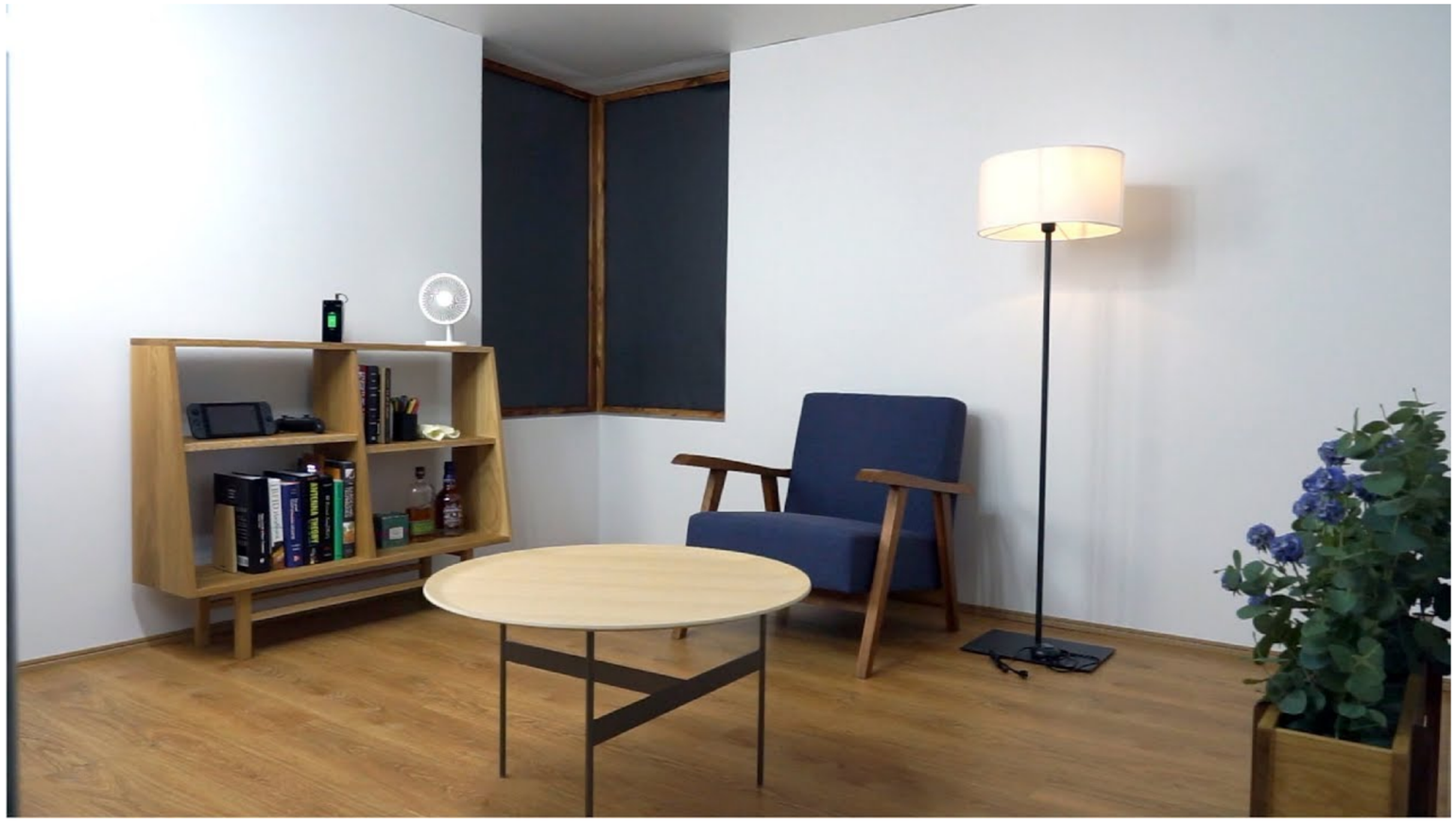
Bolt et al., Put-that-there, SIGGRAPH 1980. https://youtu.be/CbIn8p4_4CQ

Transformative Appetite

Printable and transformable **pasta-like materials**.

Wang & Yao et al., Transformative Appetite, CHI2017. https://vimeo.com/199408741

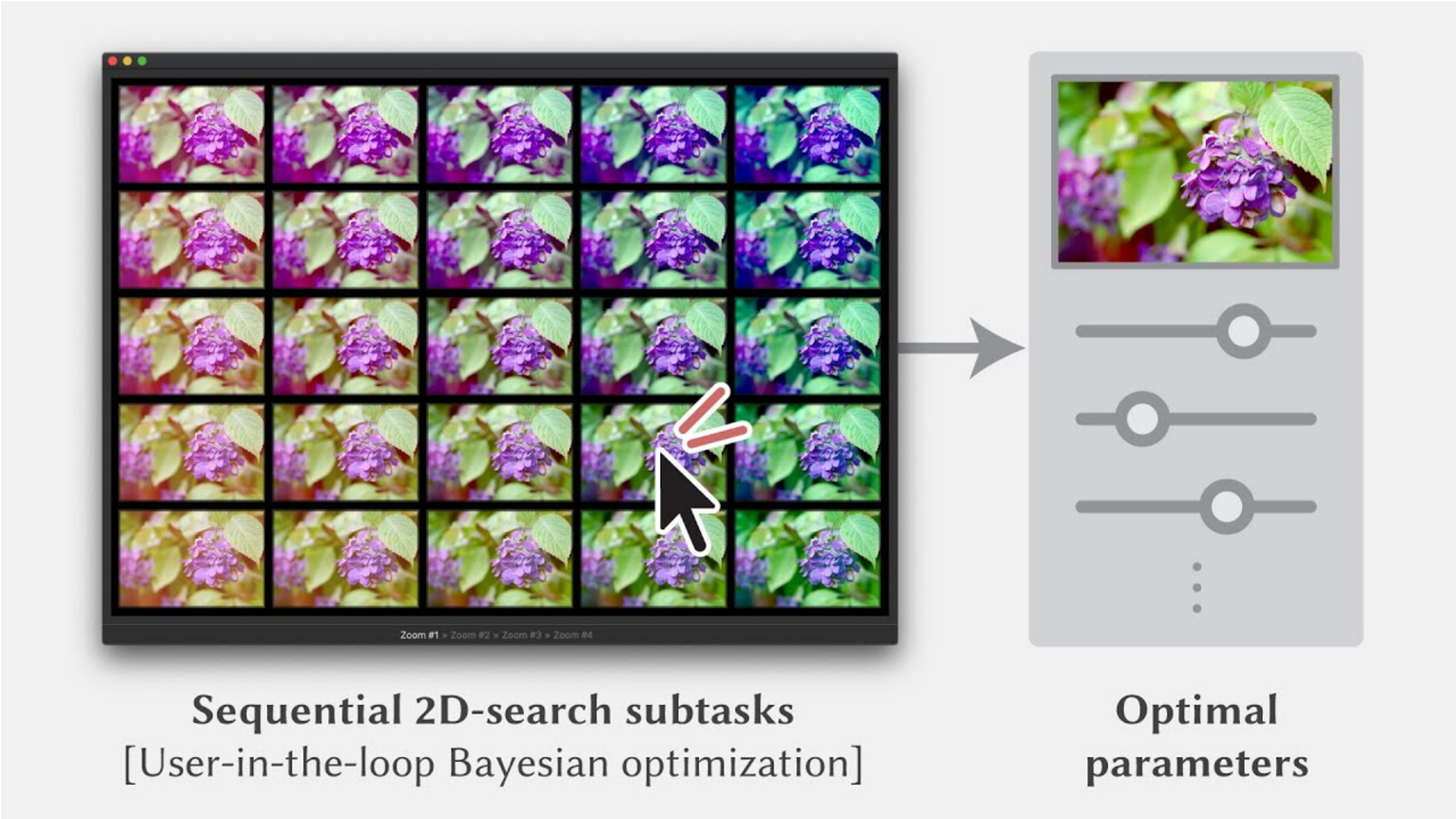
Multimode QSCR



Wireless power transfer inside a whole room.

Sasatani et al., Nature Electronics, 2021. https://youtu.be/LJd-T2BUEx8

Sequential Gallery



Interactive and computational design processes based on bayesian optimization.

Koyama et al., Sequential Gallery, TOG 2020. https://youtu.be/PmvS1ywENWA

Perfect Red

A vision video of **radical atoms** changing their shapes according to intention.

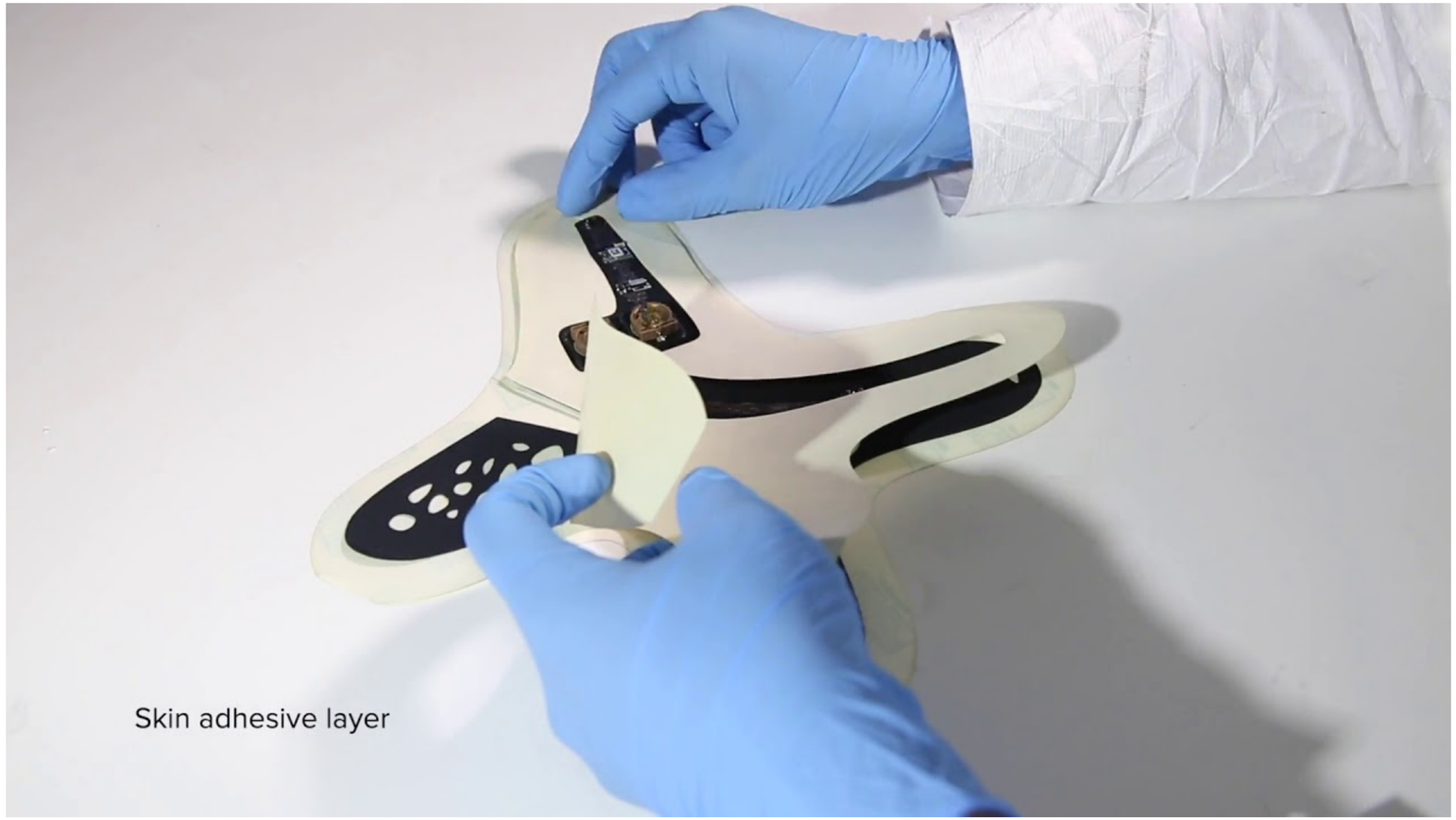
Ishii et al., Radical Atoms, Interactions 2017. https://vimeo.com/61141209

3D Printed Kinematics Dress

3D printed dress foldable into a small volume

Nervous System, Kinematic Dress, 2014. https://youtu.be/6EK9MBJiFXU

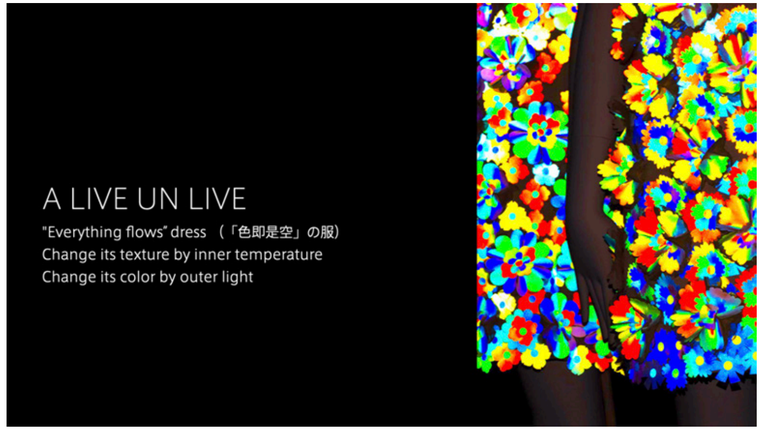
ElectroDermis



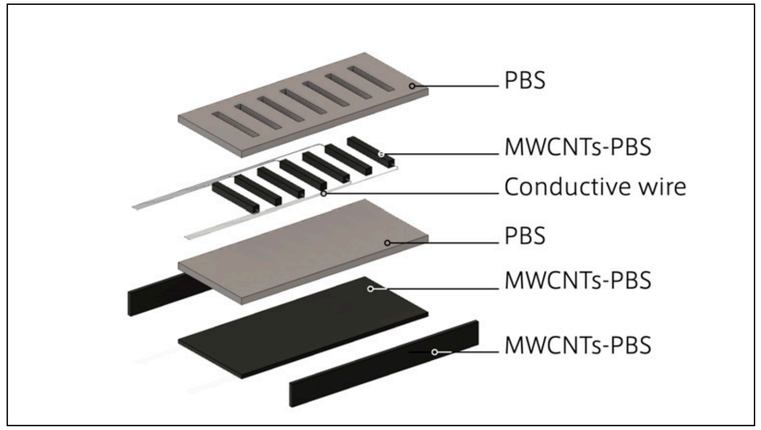
Simplified production of electronic **wearable bandages**.

Markvicka and Wang et al., ElectroDermis, CHI 2018. https://youtu.be/1kXd2099GfE

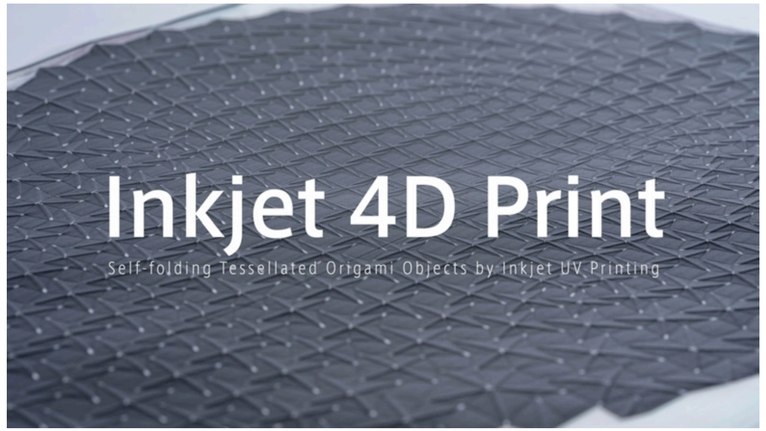
Three presentation methods



Week 3: **Slides**



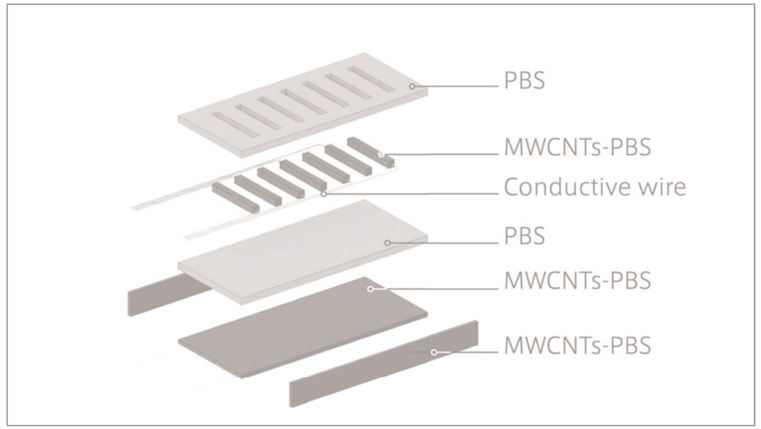
Week5: **Figures**



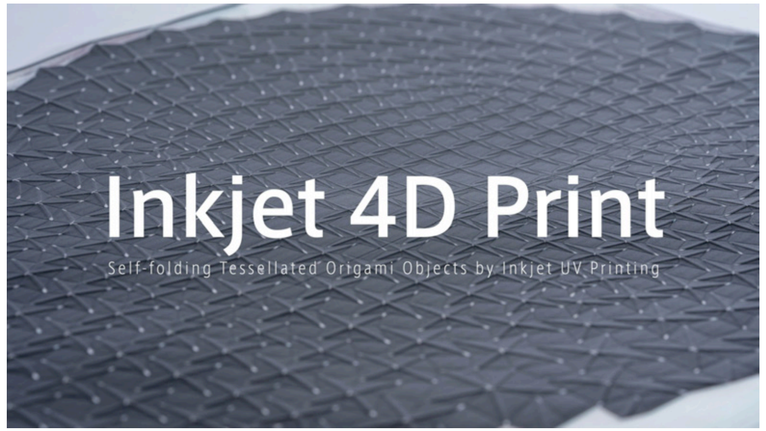
Week6: **Videos**

Three presentation methods

Week 3: **Slides**



Week5: **Figures**



Week6: **Videos**

As demonstration of what I taught in these three weeks,
I'll do my **presentation** including **slides**, **figures**, and **videos**.

Origami-inspired Computational Fabrication

Koya Narumi | Project Assistant Professor, The University of Tokyo | https://narumi.me/

SELF-INTRODUCTION

Me

Koya Narumi（鳴海 紘也 | なるみ こうや）

2011	Entered Human Science I (文科一類), UTokyo
2015	**B.Eng. @ Electrical Eng., UTokyo**
2017	M.Eng. @ Electrical Eng., UTokyo
2017	JSPS Research Fellowship @ JSPS DC1
2018	Research Scholar @ HCII, Carnegie Mellon University
2018	Researcher @ JST ACT-I
2020	Ph.D. @ Grad. School of Information Science & Technology, UTokyo
2020	Research Associate @ Interfaculty Initiative, UTokyo
2021	**Project Assist. Prof. @ Electrical Eng., Utokyo**

Research Topics

Topics: **Computational Fabrication**

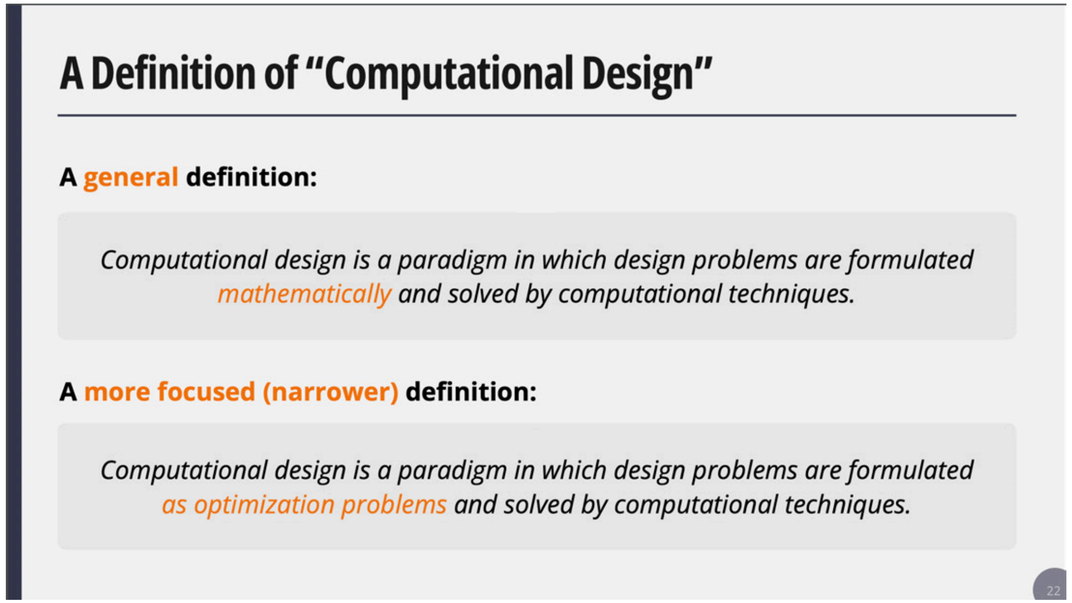
Related Fields: **Human-Computer Interaction (HCI)**
Computer Graphics (CG)
Soft Robotics

Abstract: I **design** daily products like clothes, food, mobility devices by computationally distributing special **material** and **structural** properties,. Then I **fabricate** them with digital fabrication tools like inkjet printers, 3D printers, and CNC milling machines, to create **new experiences** of users.

COMPUTATIONAL FABRICATION

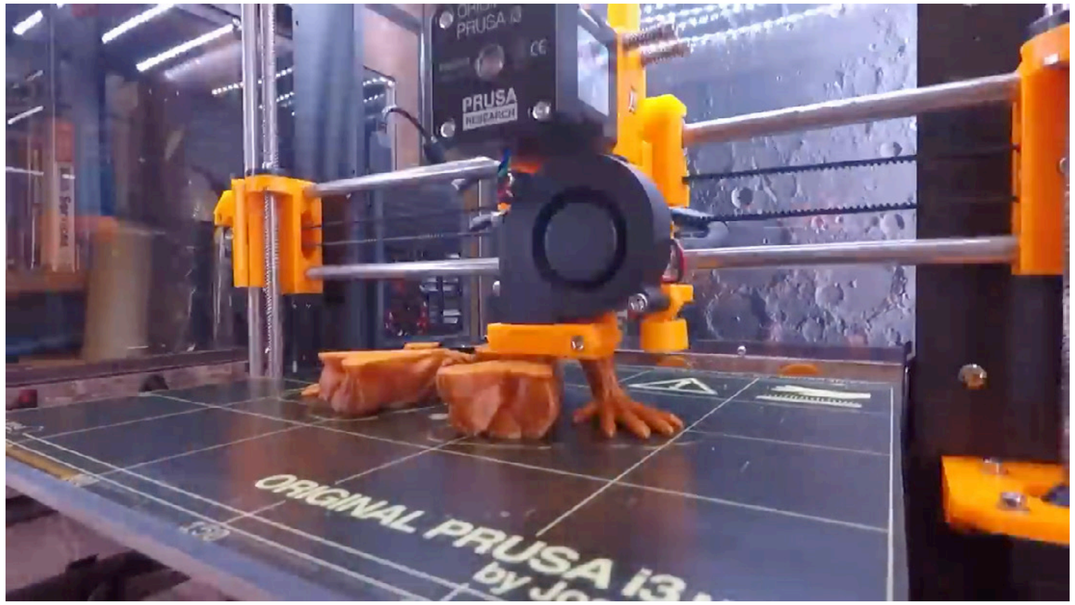
計算製造

What is Computational Fabrication?



Computational Design [1]

+

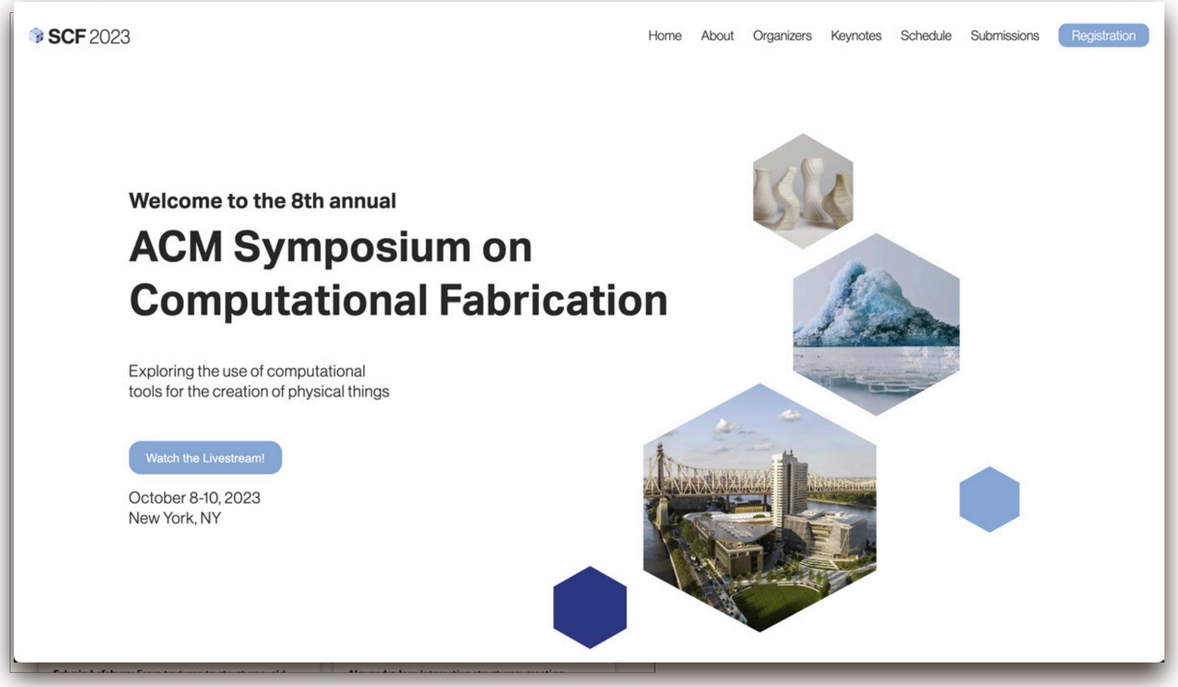


Digital Fabrication

Computational Fabrication refers to fabrication of "computationally designed objects" **under the constraints of real tools, materials, and structures**.

[1] Yuki Koyama, Introduction to Computational Design, CHI 2021 Courses.

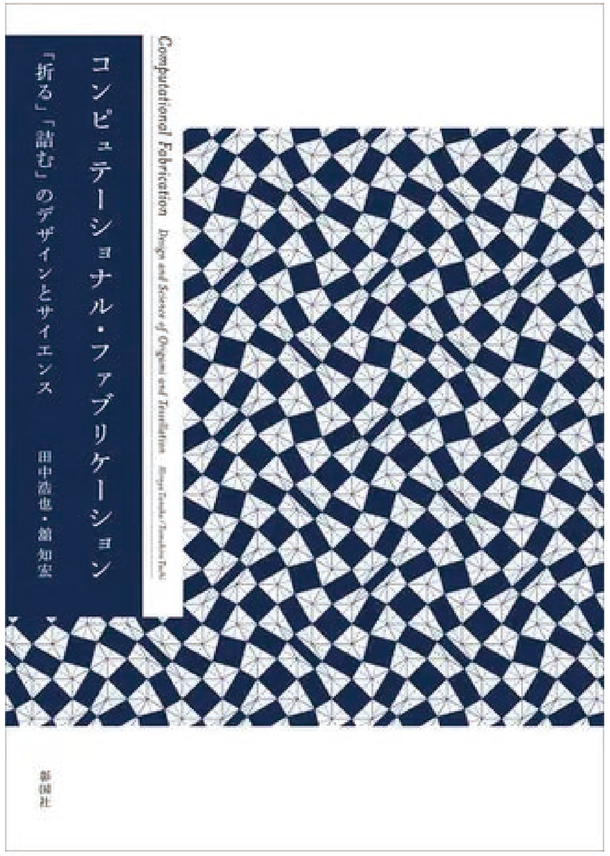
Computational Fabrication is Getting Popular



ACM Symposium on Computational Fabrication (SCF)
2016-
https://scf.acm.org/2023/index.html

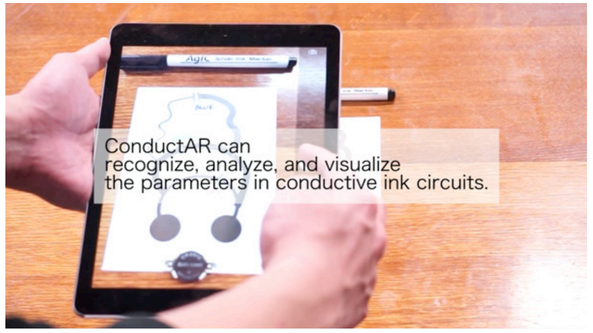
Computational Fabrication Seminar
2021-
https://computational-fabrication.org/

Book about Computational Fabrication

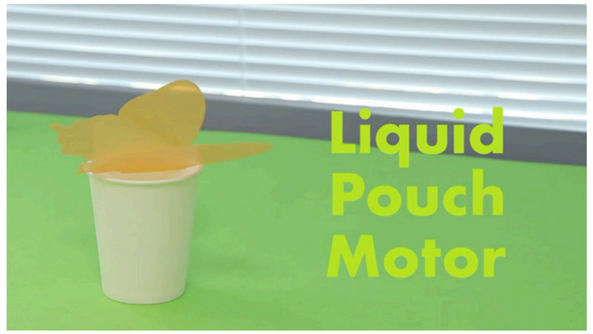


Computational Fabrication:
Design and Science of Origami and Tessellation
Hiroya Tanaka & Tomohiro Tachi, 2020.

Circuit Eraser
ACM CHI EA 2015, Kickstarter

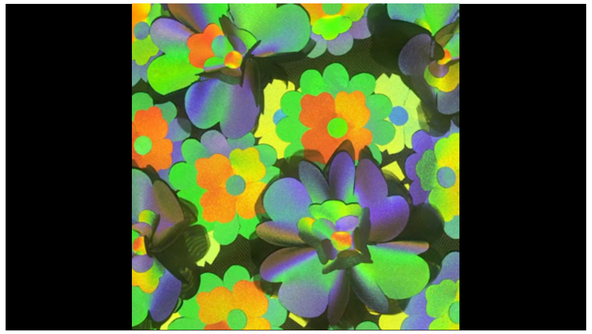


ConductAR
ACM UbiComp 2016

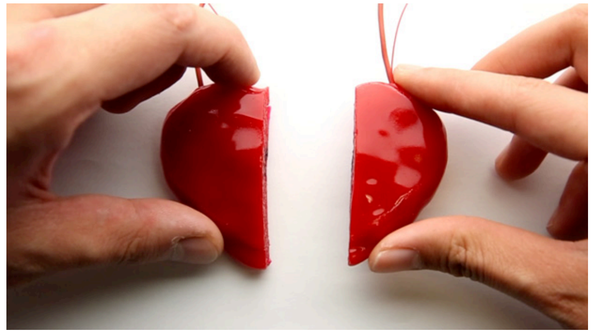


Liquid Pouch motors
IEEE ICRA 2017, IEEE RA-L 2020

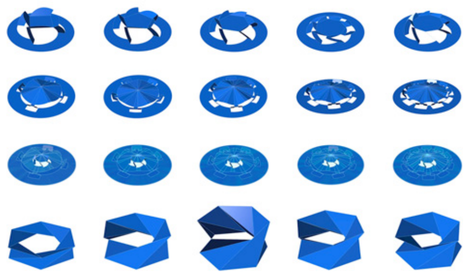
Papilion
Ars Electronica 2017



A LIVE UN LIVE
Roppongi Corssing 2018



Self-healing UI
ACM UIST 2019

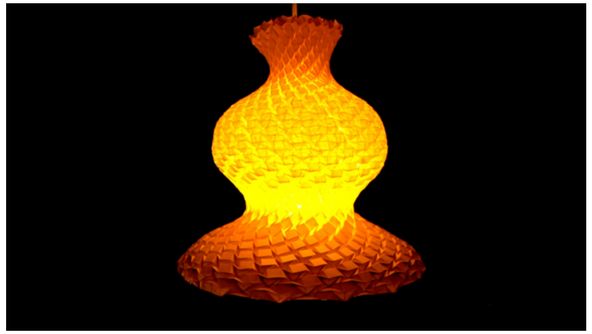


Kirigami Haptic Swatches
ACM CHI 2020

Pop-up Print
ACM UIST 2020

poimo
ACM UIST 2020, 他

Flower Jelly Printer
ACM CHI 2021

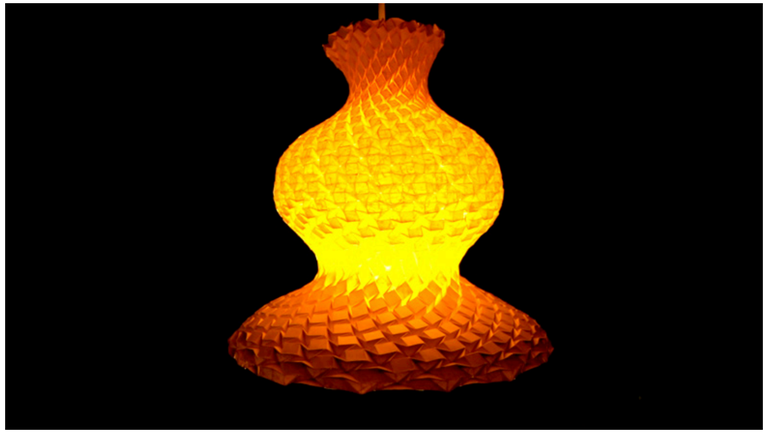


Crane
ACM TOCHI (CHI) 2023

Inkjet 4D Print
ACM TOG (SIGGRAPH) 2023

Origami-inspired Computational Fabrication

Pop-up Print
ACM UIST 2020

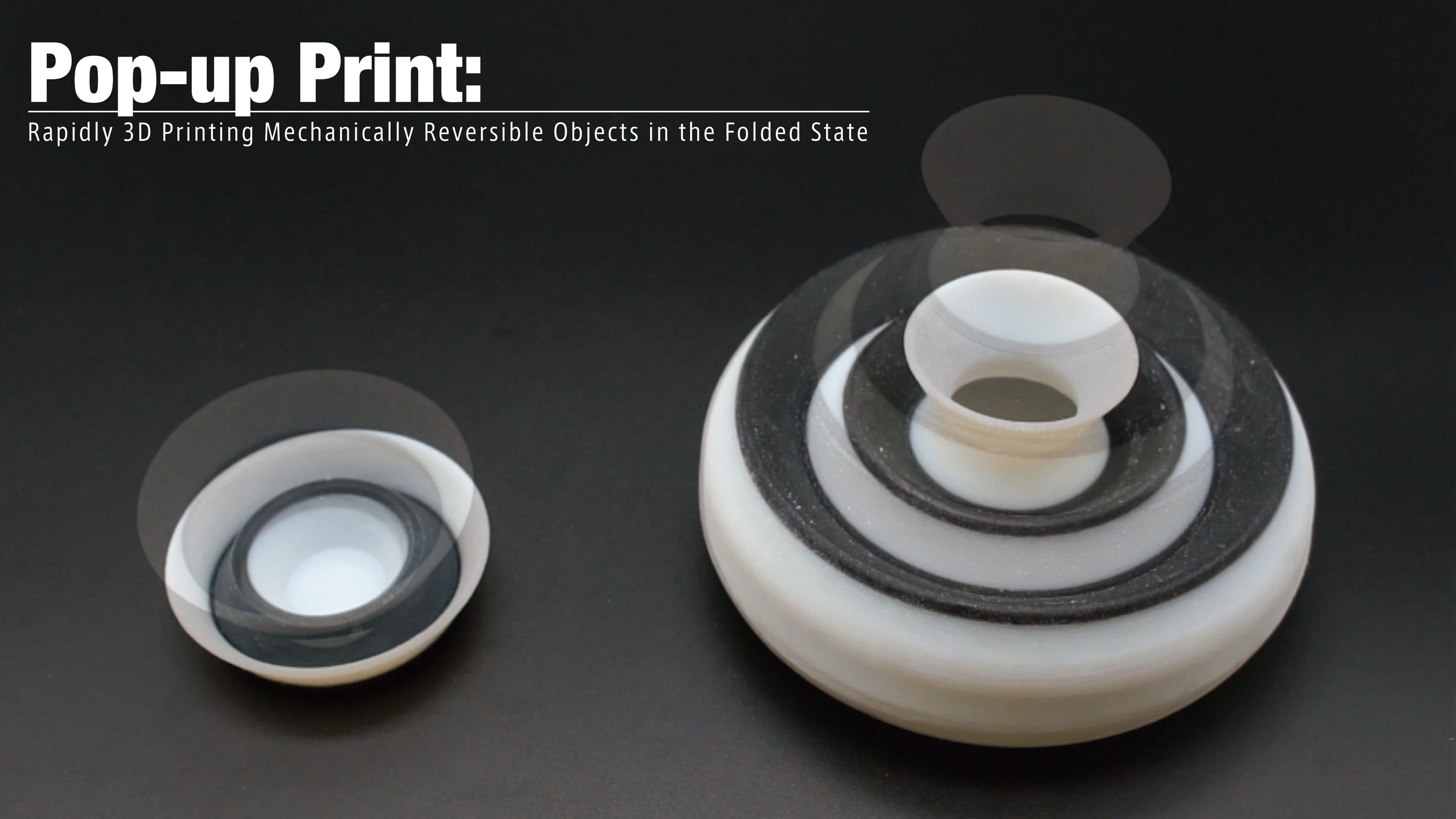


Crane
ACM TOCHI (CHI) 2023

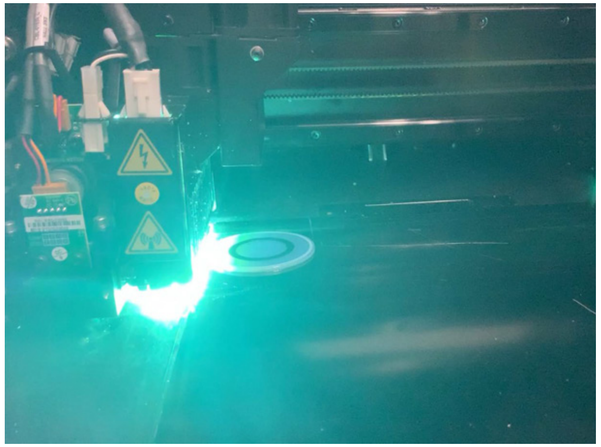
Inkjet 4D Print
ACM TOG (SIGGRAPH) 2023

Pop-up Print:

Rapidly 3D Printing Mechanically Reversible Objects in the Folded State

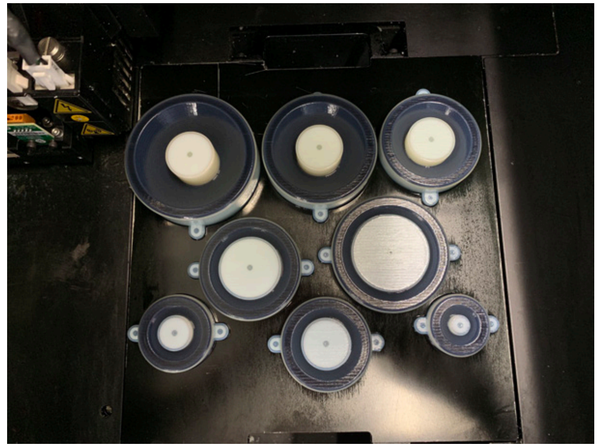


Problems in 3D Printing Tall Objects



Longer printing time

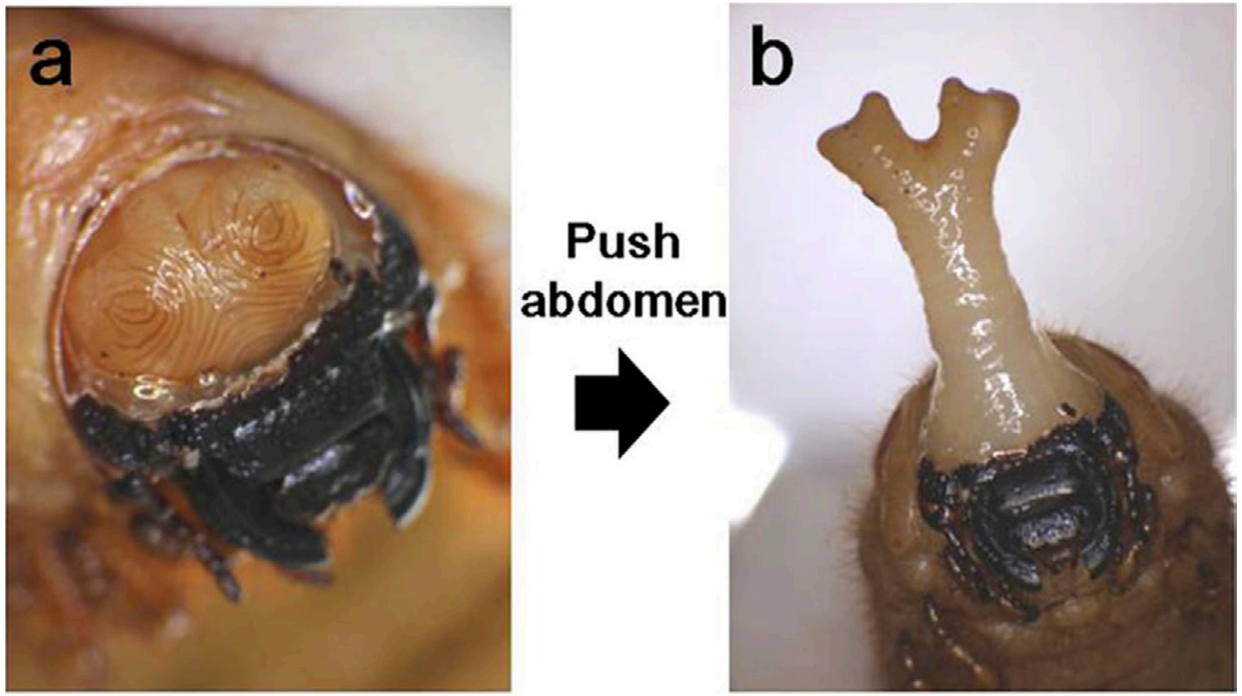
Larger support material consumption



More storage space

The smaller the object is, **the better** for 3D printing

“Inverse Origami” of Beetle’s Chrysalis



[1]

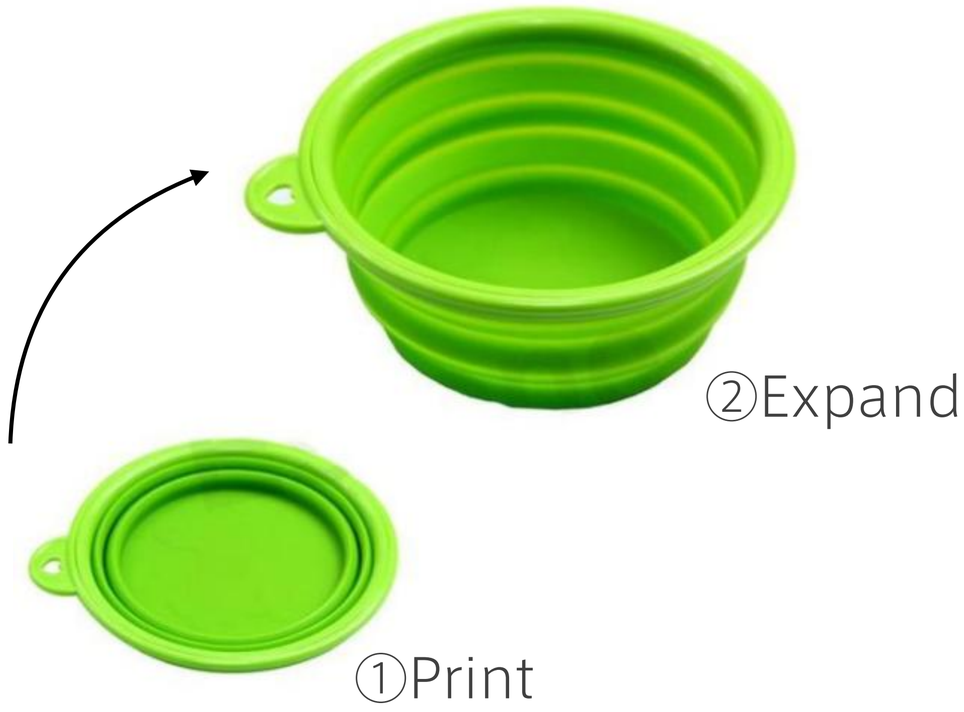
Beetle inside a chrysalis

Adult beetle

In the chrysalis state, the beetle has a **folded horn**, which is called **inverse origami** [2]

[1] Matsuda et al., *Scientific Reports*, 2017.
[2] 近藤滋，生物の形づくりの謎解く“カブトムシ角風船” (in Japanese)

Idea of Inverse Origami 3D Print



①**Print an object** in a folded state, and ②**expand it** afterward

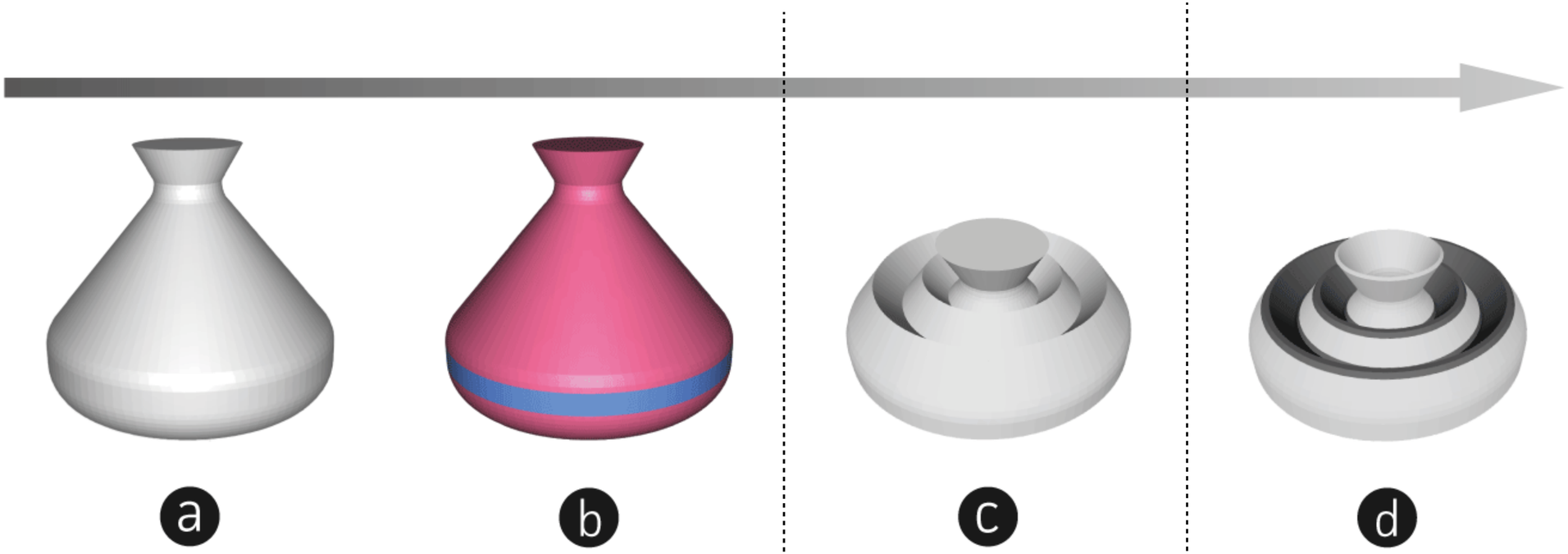
POP-UP PRINT

Rapidly 3D Printing Mechanically Reversible Objects in the Folded State

Yuta Noma, Koya Narumi, Fuminori Okuya, Yoshihiro Kawahara

The University of Tokyo

Overview



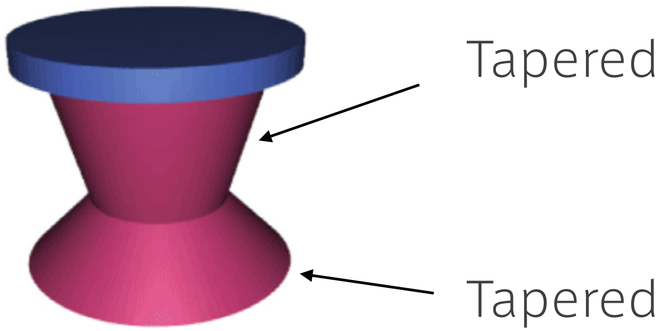
From an input STL file,
the system **visualize** foldable regions

Fold a model

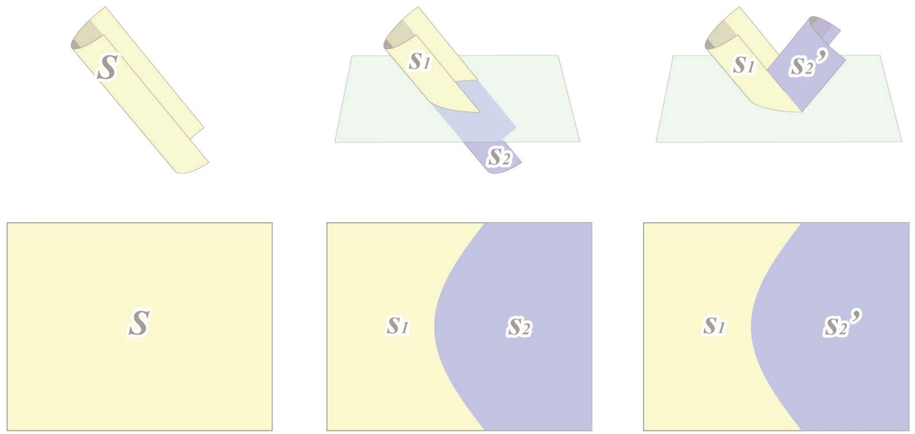
Thicken and **distribute**
soft materials to hinges

Noma et al., Pop-up Print, UIST 2020.

How to Fold with Pop-up Print



① Extract **tapered regions**

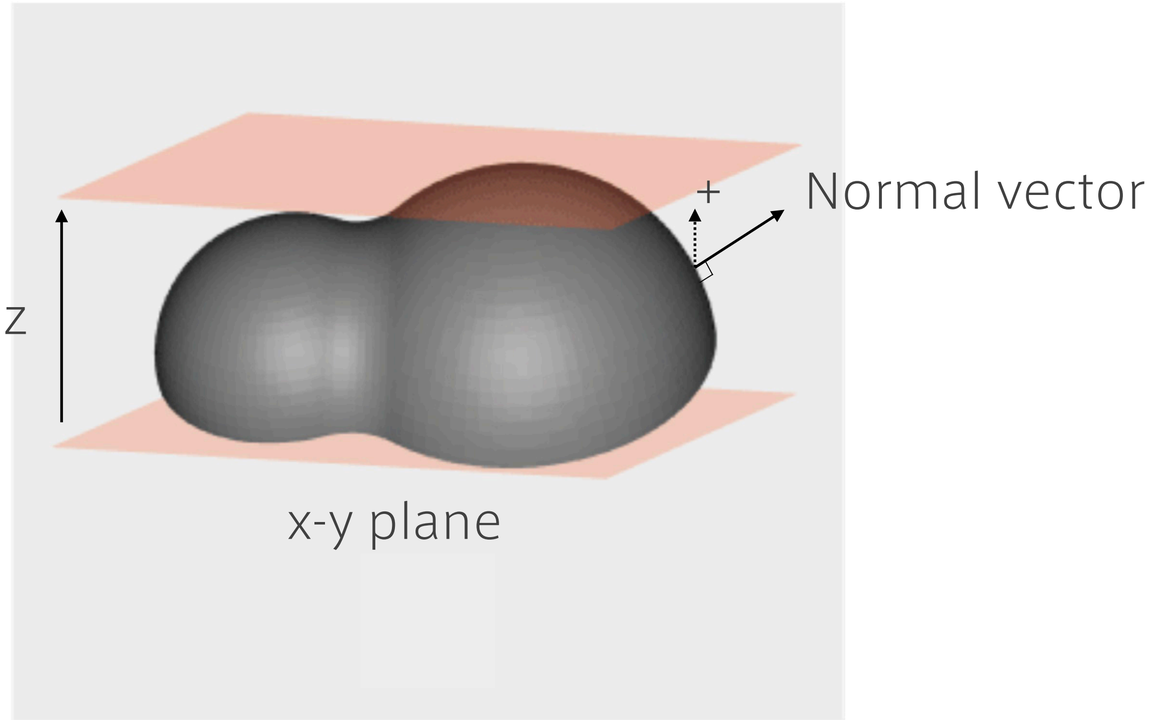


[1]

② Apply **planar folding** to each tapered region

[1] Mitani and Igarashi, Pacific Graphics, 2011.

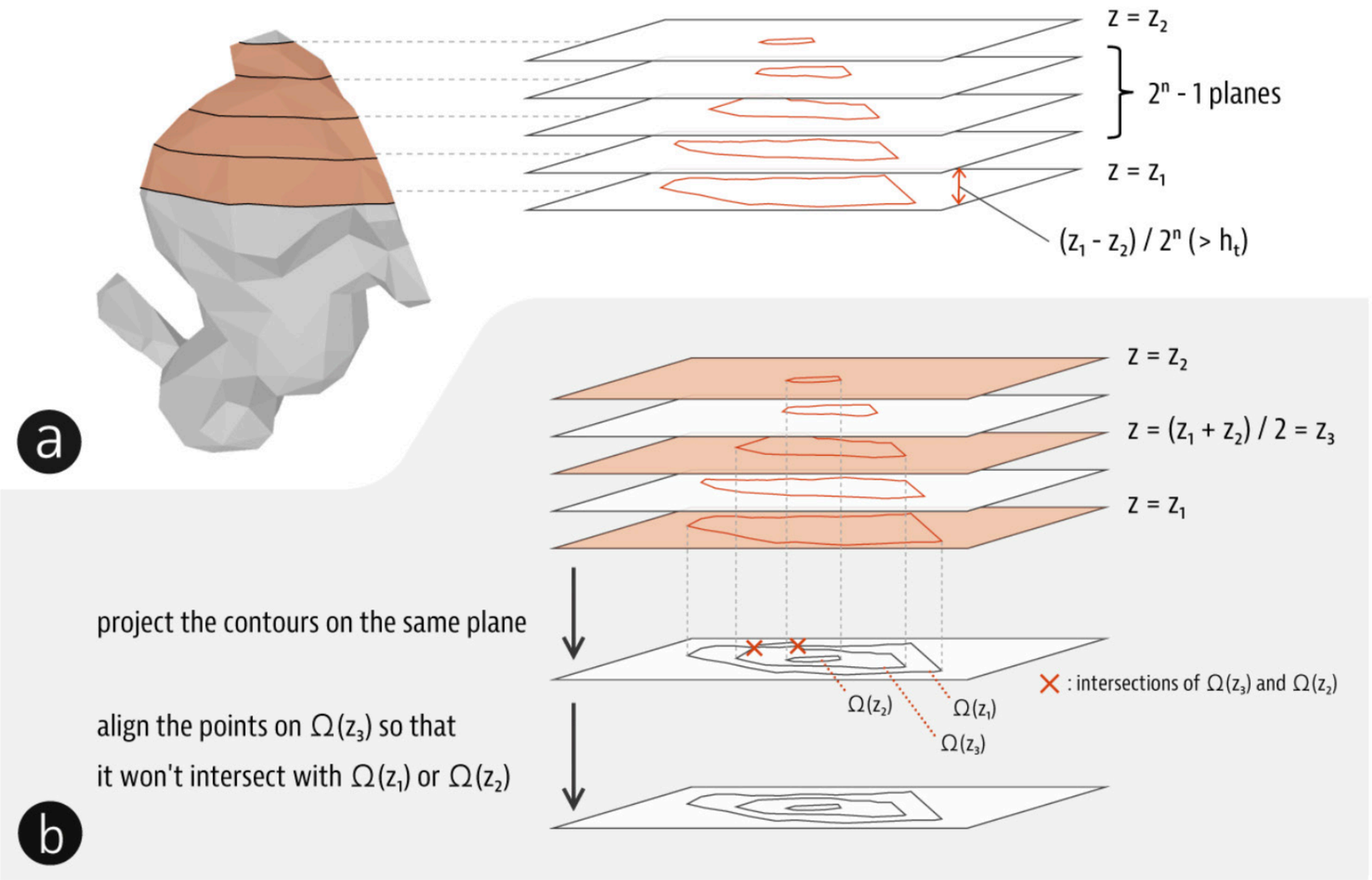
① Extract Tapered Region



Z-components of all the normal vectors are plus ⇔ the surface is tapered [2]

[2] Wolff et al., Computer Graphics Forum, 2018.

Augmentation of Tapered Region



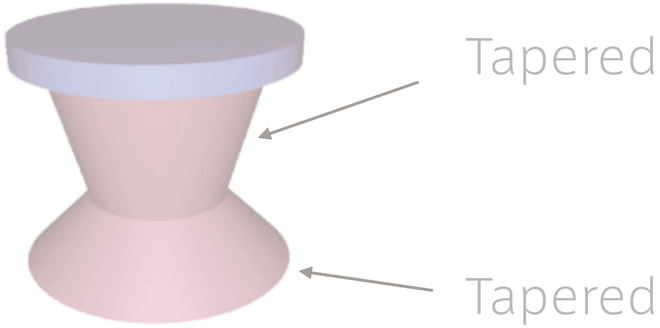
In reality, many surfaces are NOT tapered in their original shape

↓

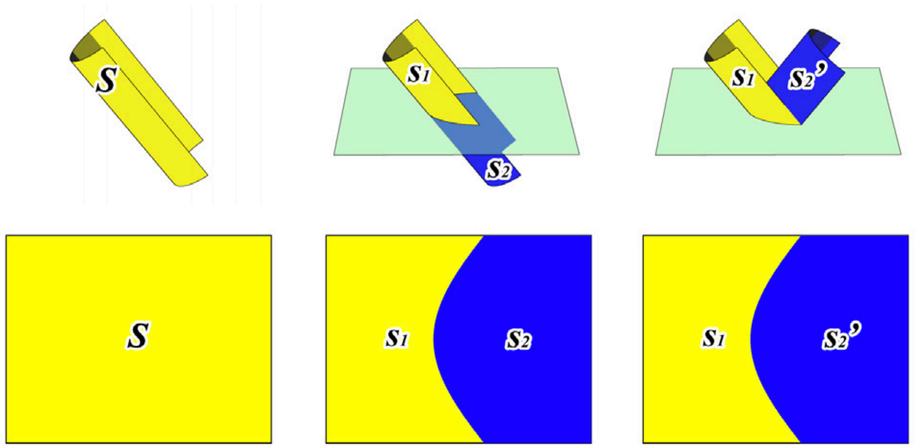
Modify the mesh pattern to enlarge the tapered region

Noma et al., Pop-up Print, UIST 2020.

How to Fold with Pop-up Print



① Extract **tapered regions**



[1]

② Apply **"planar folding"** to each tapered region

[1] Mitani and Igarashi, Pacific Graphics, 2011.

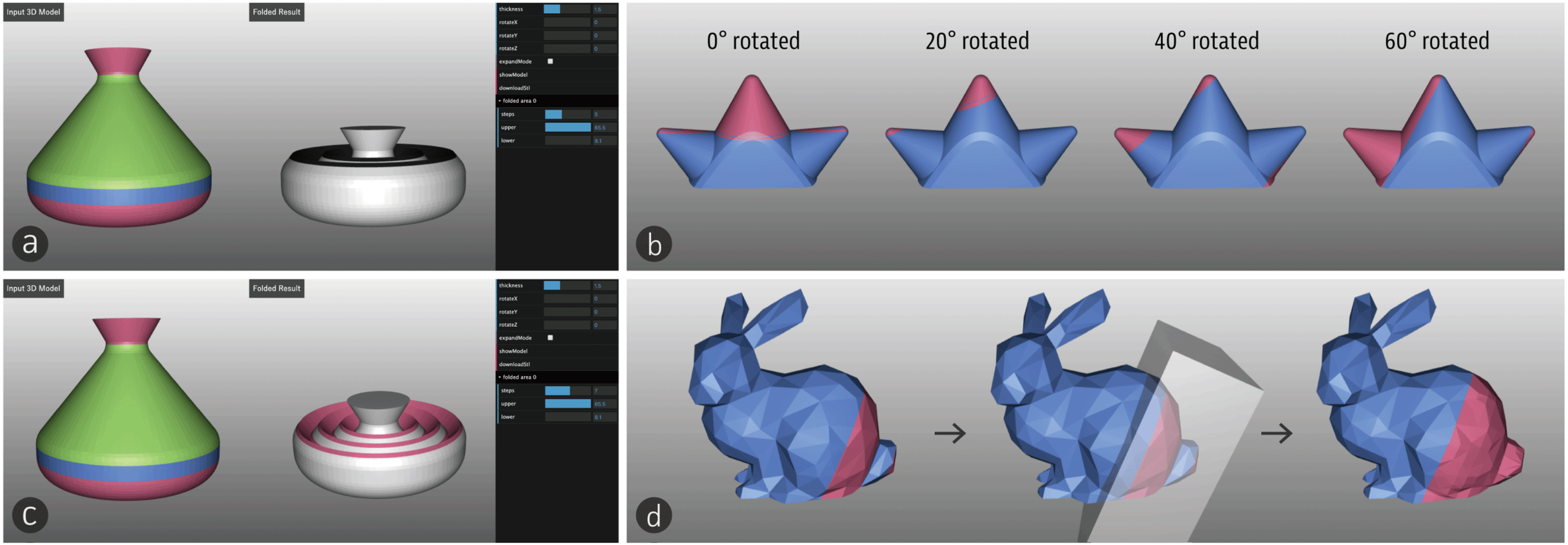
Bistability of the Structure

Bad example of **non**-bistable Pop-up

For practical use, the structure needs to be **mechanically bistable** between folded and unfolded states

Noma et al., Pop-up Print, UIST 2020.

Interactive Software

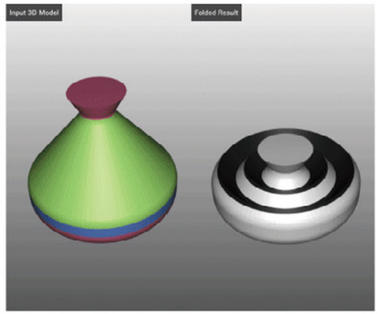
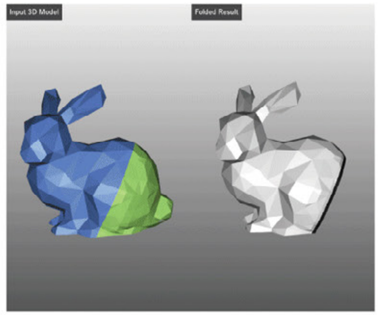


The system visualizes **foldable regions in red**

Users can **enlarge a foldable region** by dragging and selecting the region

Noma et al., Pop-up Print, UIST 2020.

Evaluation of Pop-up Structure

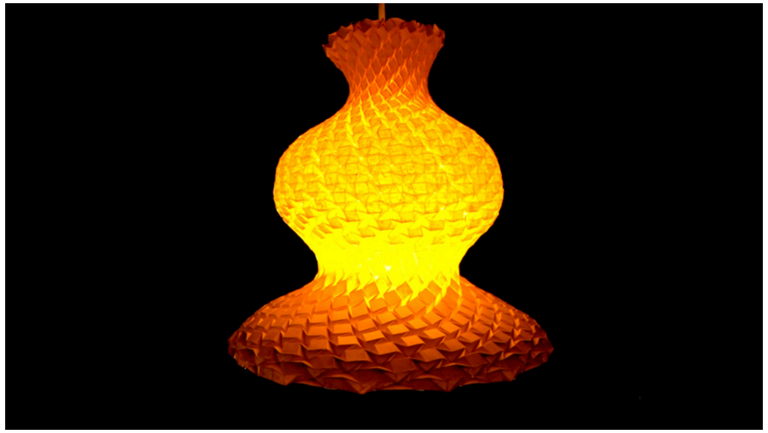
name	properties *1	view of design tool	printed objects
Tokkuri (& Choko)	***without folding*** print time: 10 h 24 min support: 477 g ***folded*** print time: 5 h 20 min support: 342 g		
Stanford Bunny	***without folding*** print time: 7 h 16 min support: 149 g ***folded*** print time: 5 h 25 min support: 141 g		

In the best case, **the printing time and support materials consumption decrease to 1/5**

Noma et al., Pop-up Print, UIST 2020.

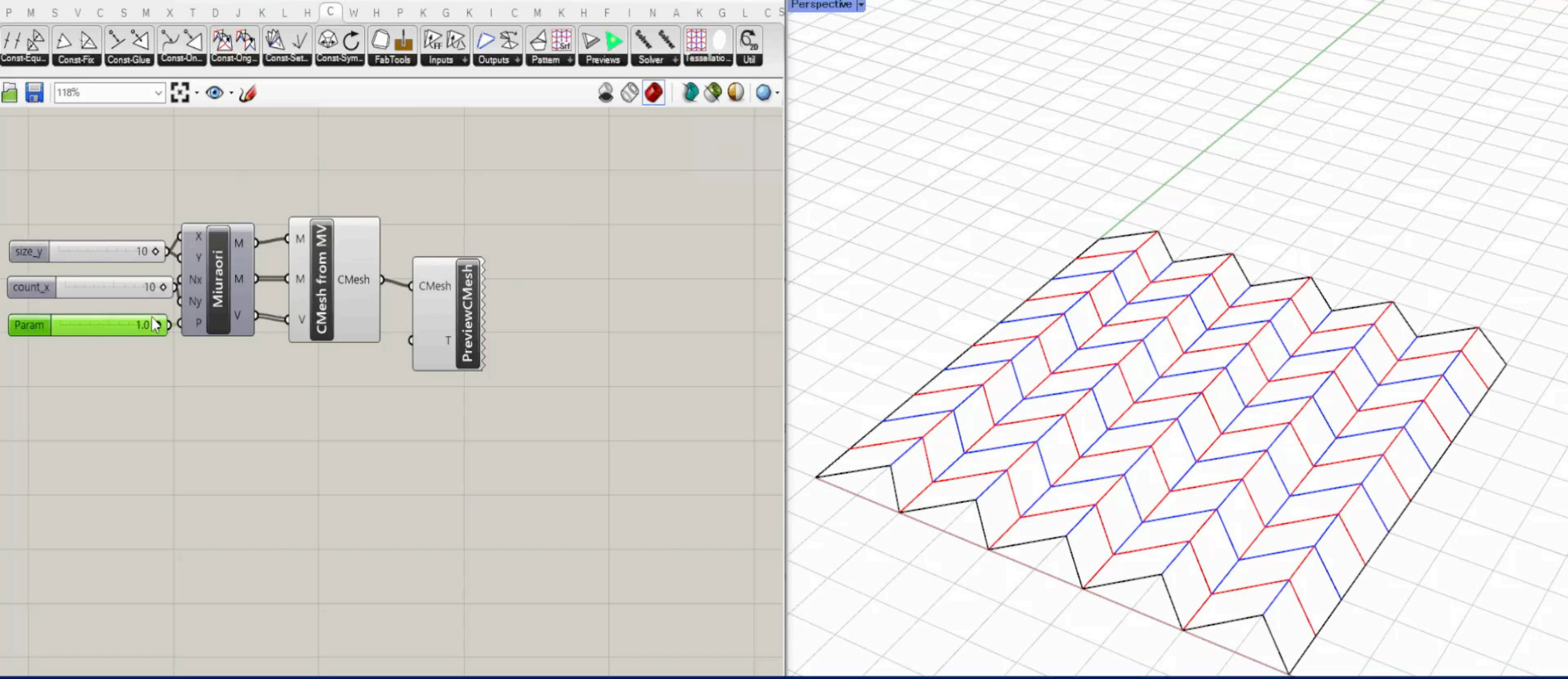
Origami-inspired Computational Fabrication

Pop-up Print
ACM UIST 2020



Crane
ACM TOCHI (CHI) 2023

Inkjet 4D Print
ACM TOG (SIGGRAPH) 2023



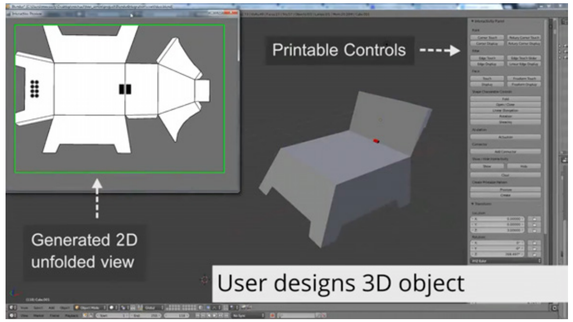
CRANE

An Integrated Computational Design Platform for Functional, Foldable, and Fabricable Origami Products

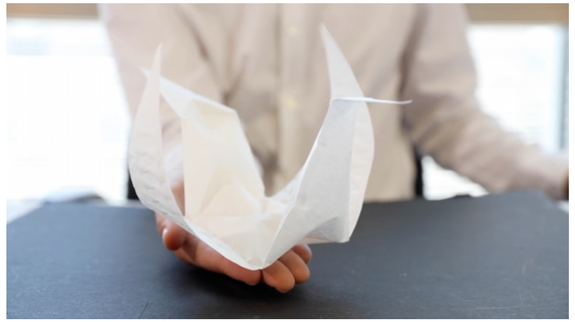
Kai Suto, Yuta Noma, Kotaro Tanimichi, Koya Narumi, Tomohiro Tachi
The University of Tokyo, Nature Architects, Inc.

HCI people love **origami fabrication**

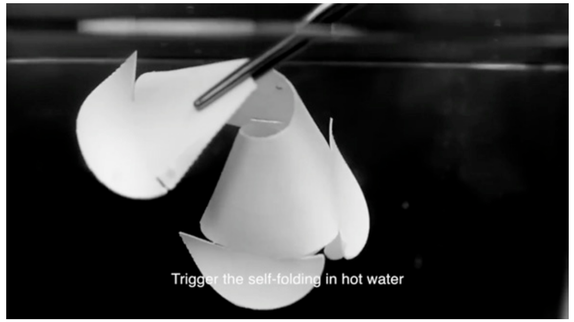
LaserOrigami (CHI'13)



Foldio (UIST'15)



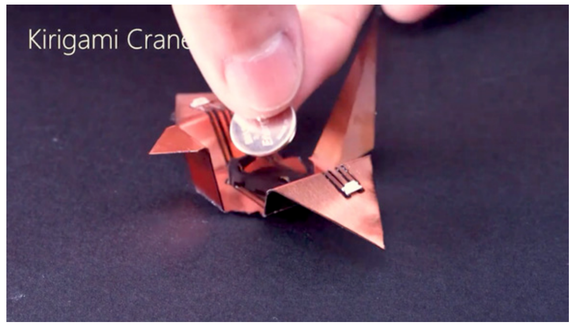
aeroMorph (UIST'16)



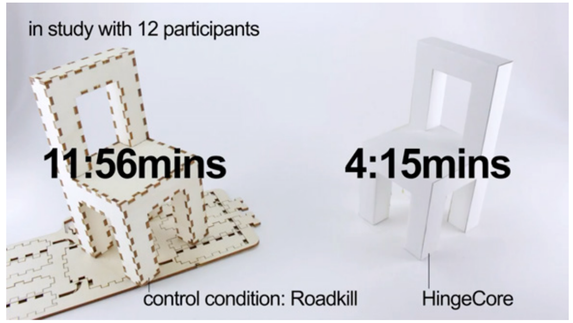
Thermorph (CHI'18)

Kirigami Haptic Swatches (CHI'20)

Flaticulation (UIST'22)

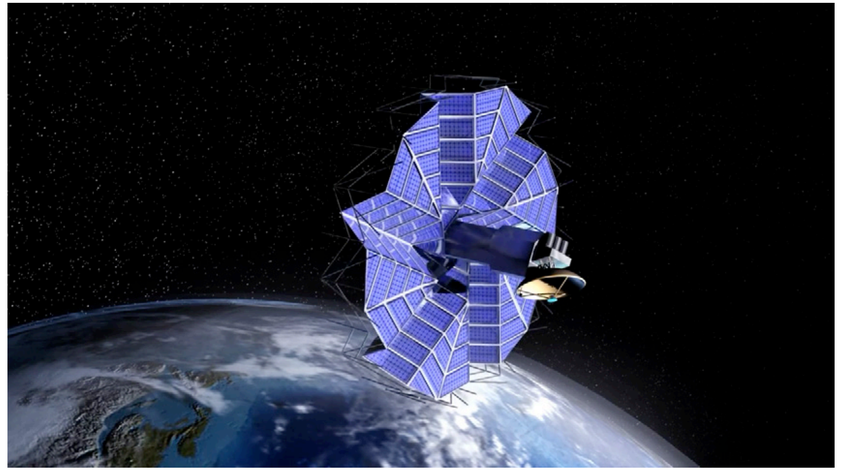


Fibercuit (UIST'22)

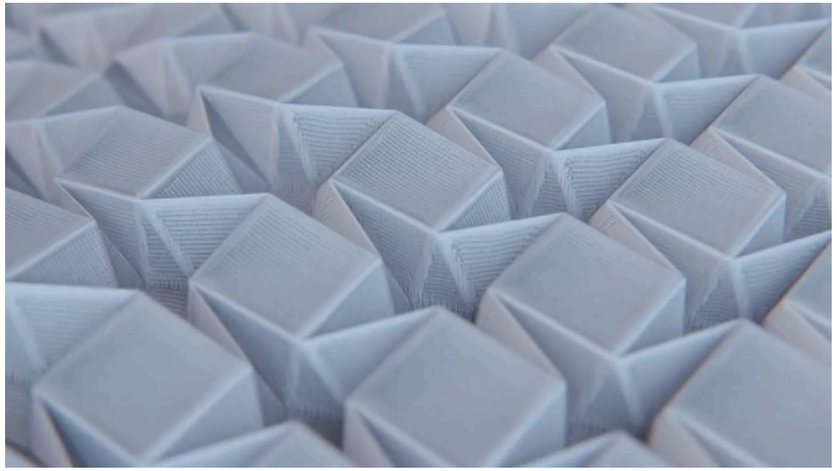


HingeCore (UIST'22)

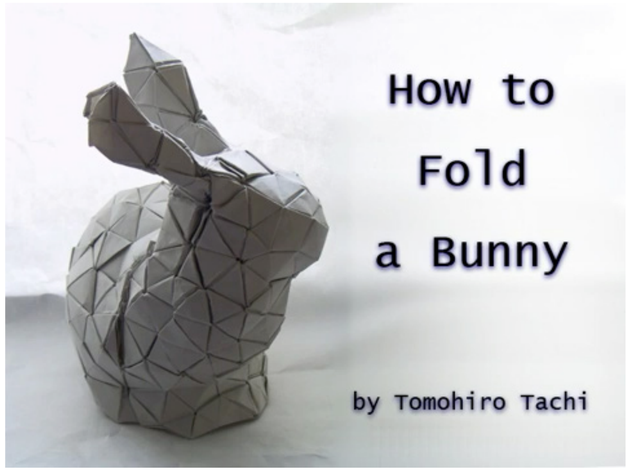
However, origami **design** has much more!



Space engineering [1]



Garments [2]



Any polyhedron [3]

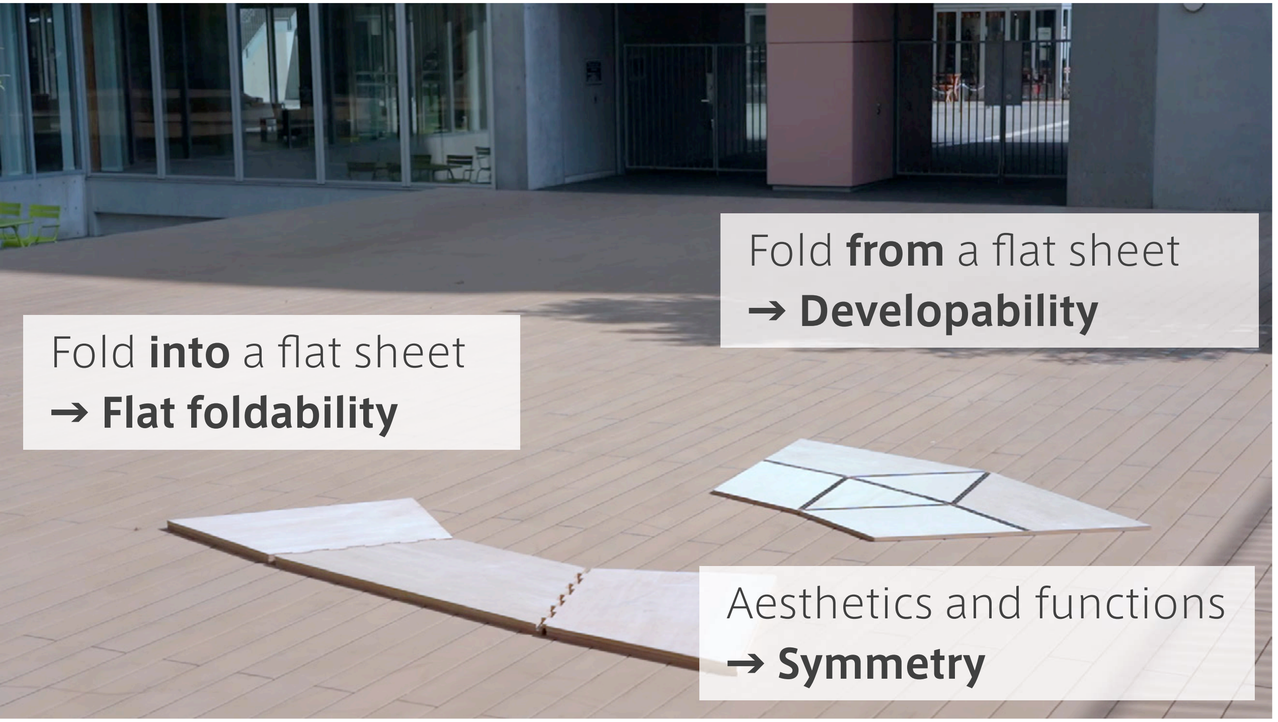
More **sophisticated origami design** is required in **engineering**, **industry**, and **mathematics**.

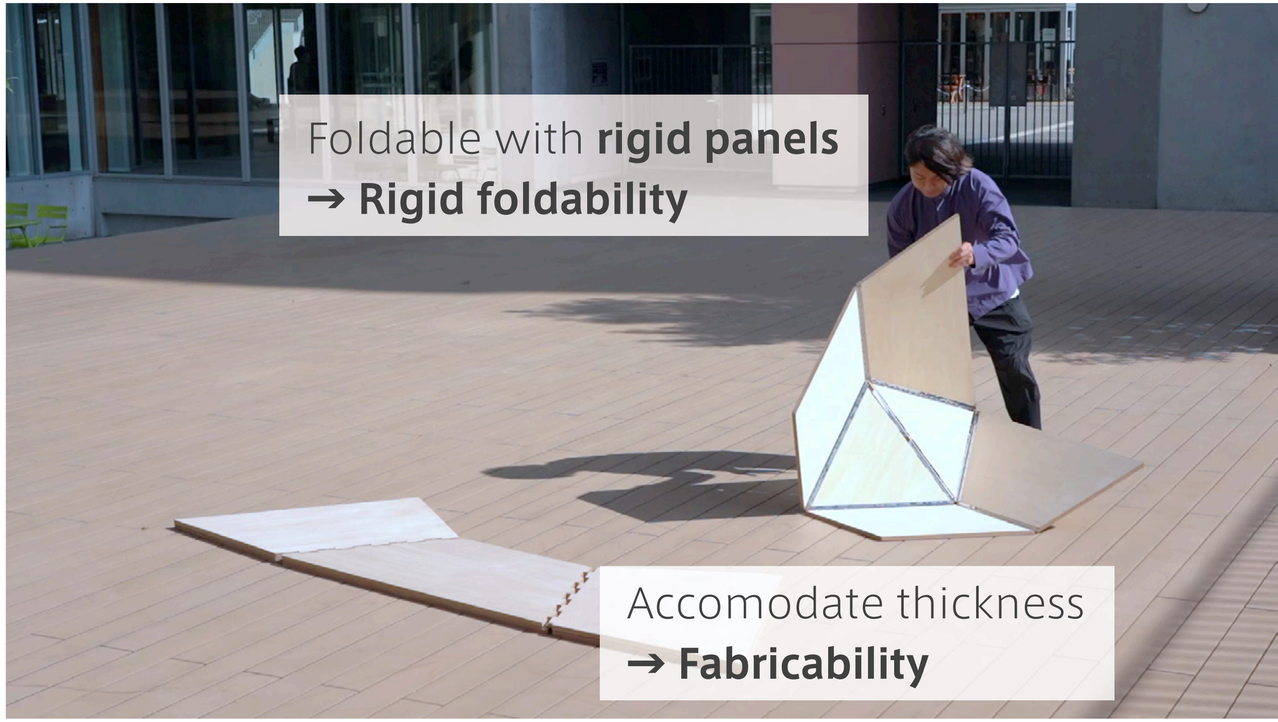
[1] BYU, Origami in Space, 2013 [2] ISSEY MIYAKE, Steam Stretch, 2014 [3] Tachi, How to Fold a Bunny, 2009

Can we easily make them?

At a first glance, **these origami products seem simple**.

Can we easily make them?



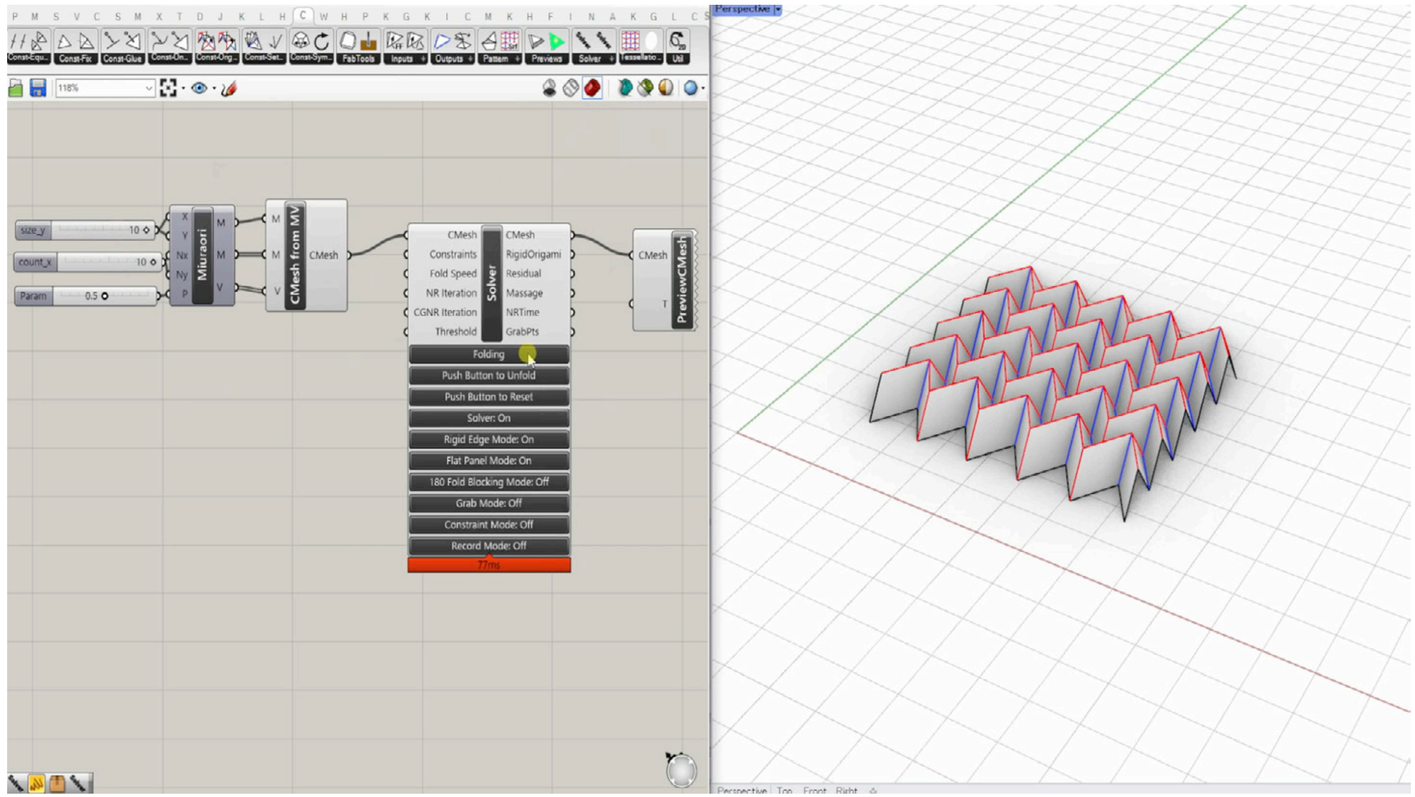


In reality, **mathematically feasible origami products are difficult**.

CRANE

An Integrated Computational Design Platform for Functional, Foldable, and Fabricable Origami Products

Crane's GUI



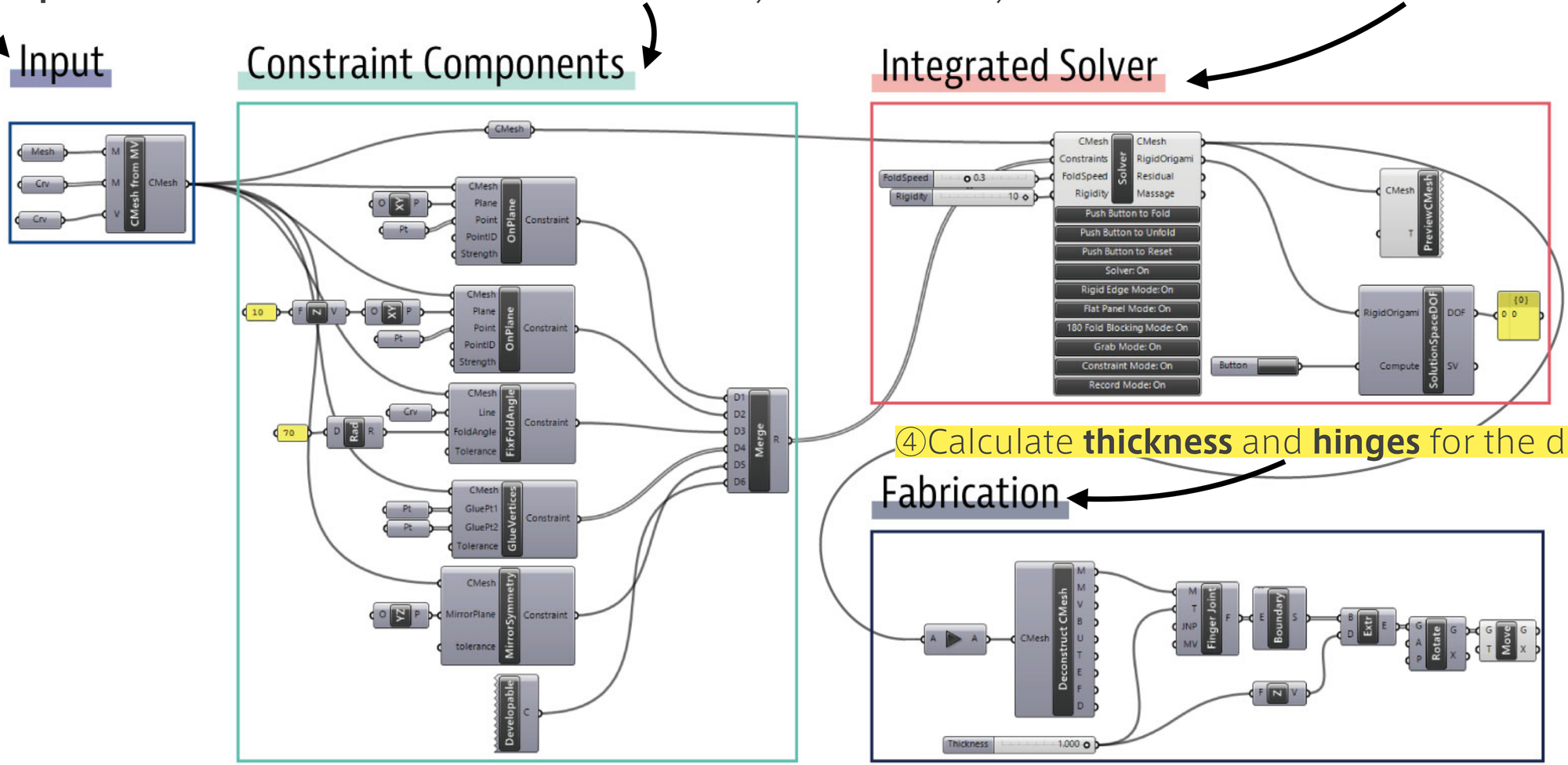
Crane is implemented on Rhino/Grasshopper,
with **a visual programming environment and a CAD visualizer**.

Crane overview

①**Give input**

②**Put constraints** for functionality and foldability

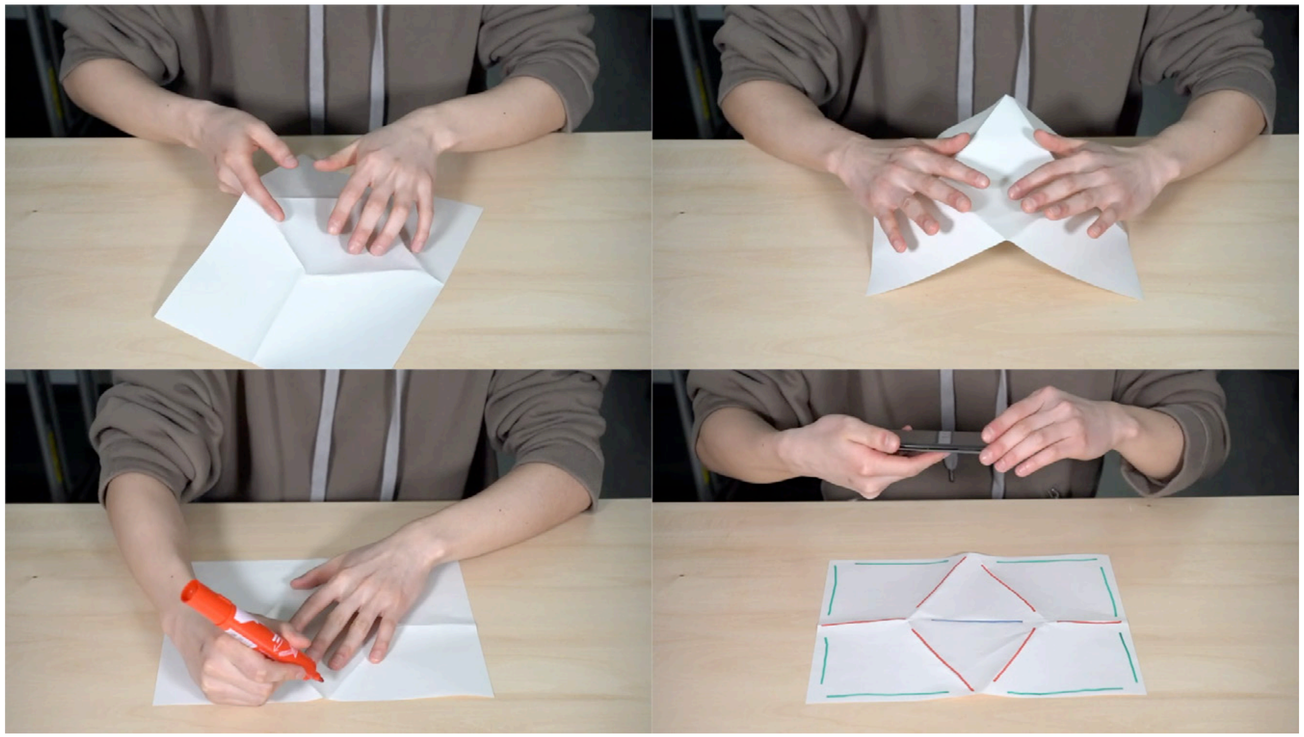
③**Conduct Simulation and form-finding**



④Calculate **thickness** and **hinges** for the desired tools

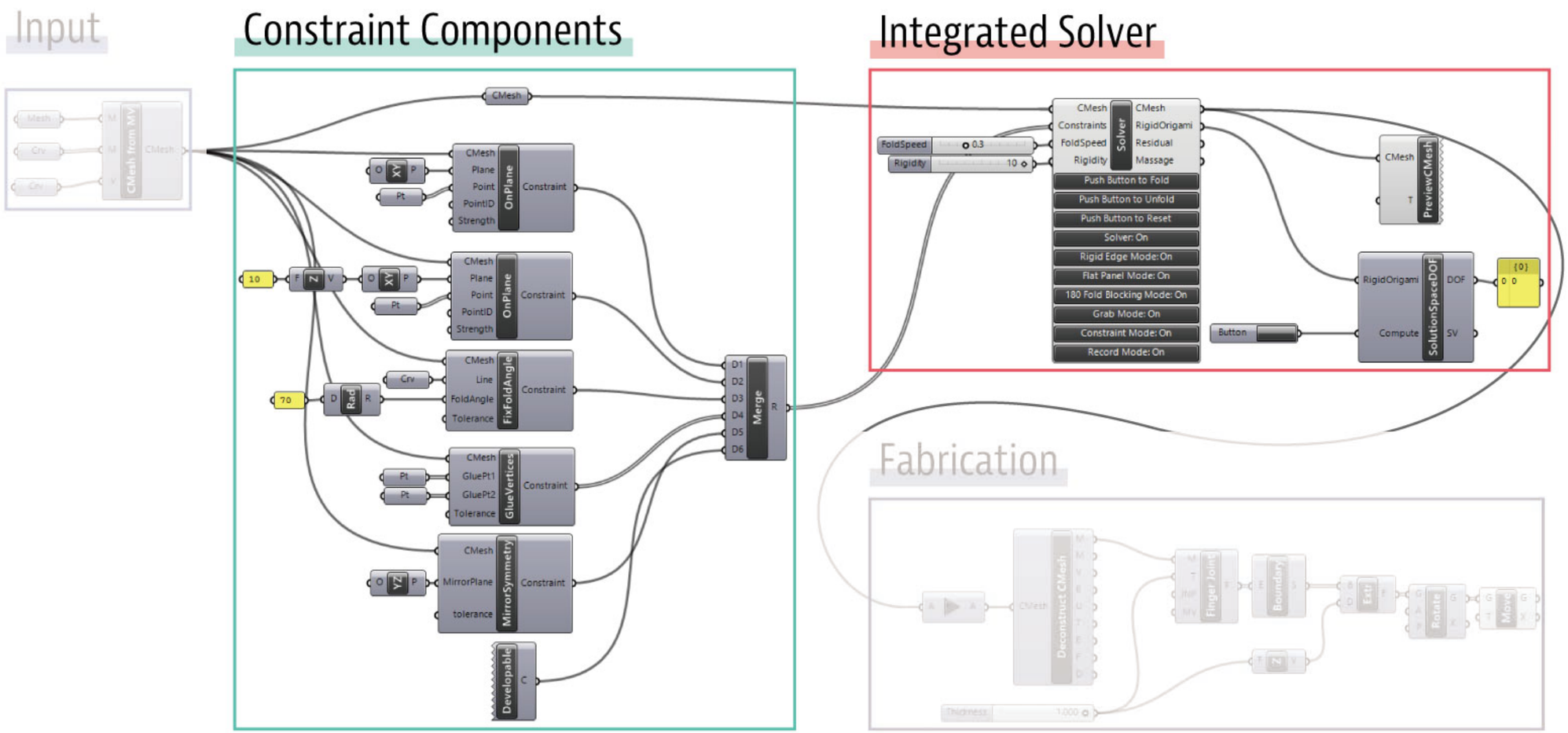
Fabrication

Step 1: input

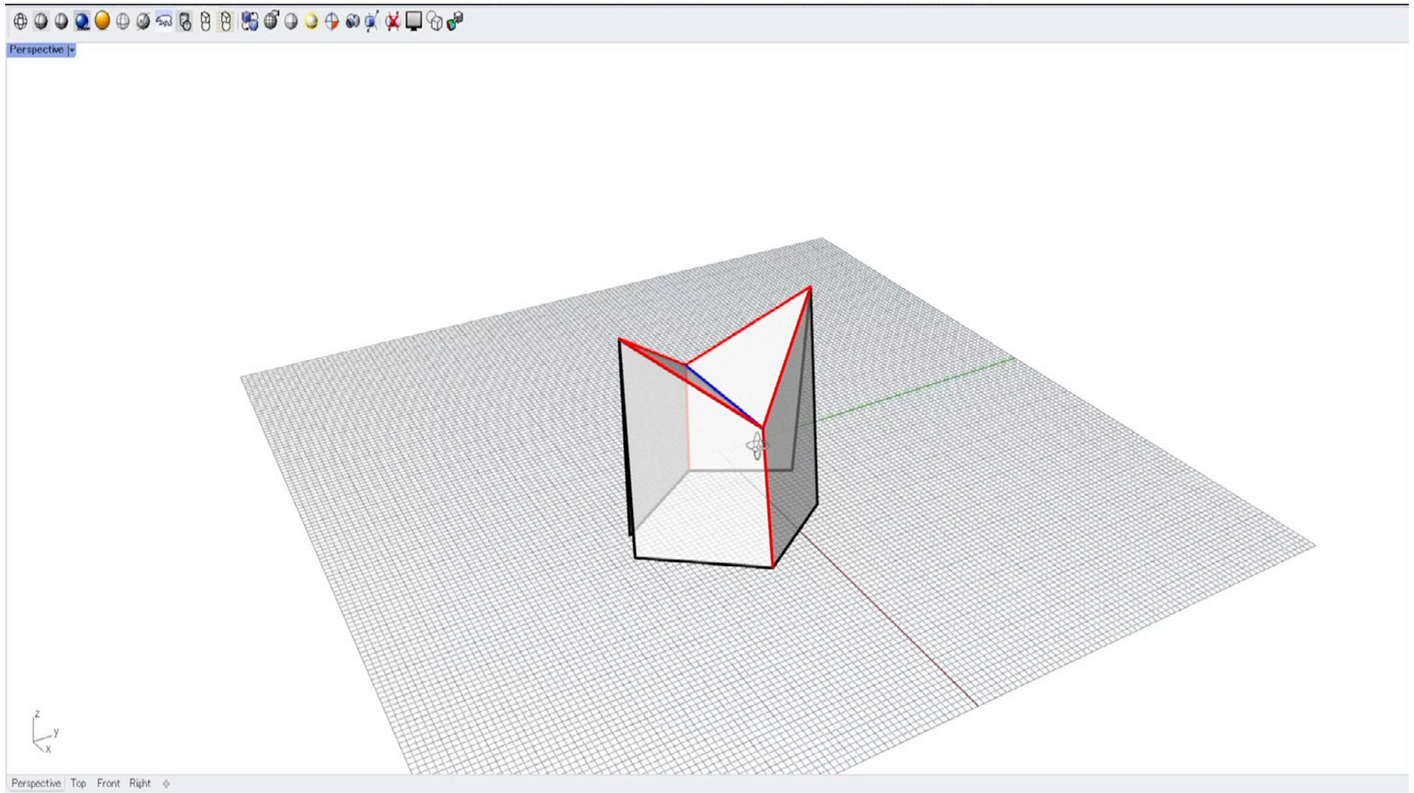


The system converts **a photo of origami to a 2D origami pattern** for post-processing.
Users **manually prototype**, assign colors (mountain, valley, boundary), and take a photo.

Step 2: Simulation and form-finding



Step 2: Simulation and form-finding



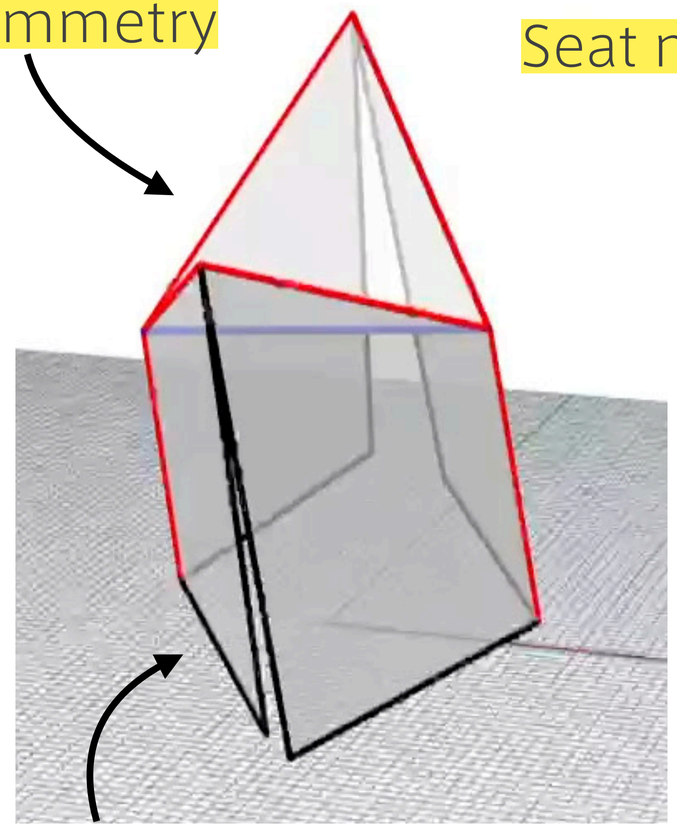
The system **simulates the folding transformation**.
However, this “chair“ is bad as a chair.

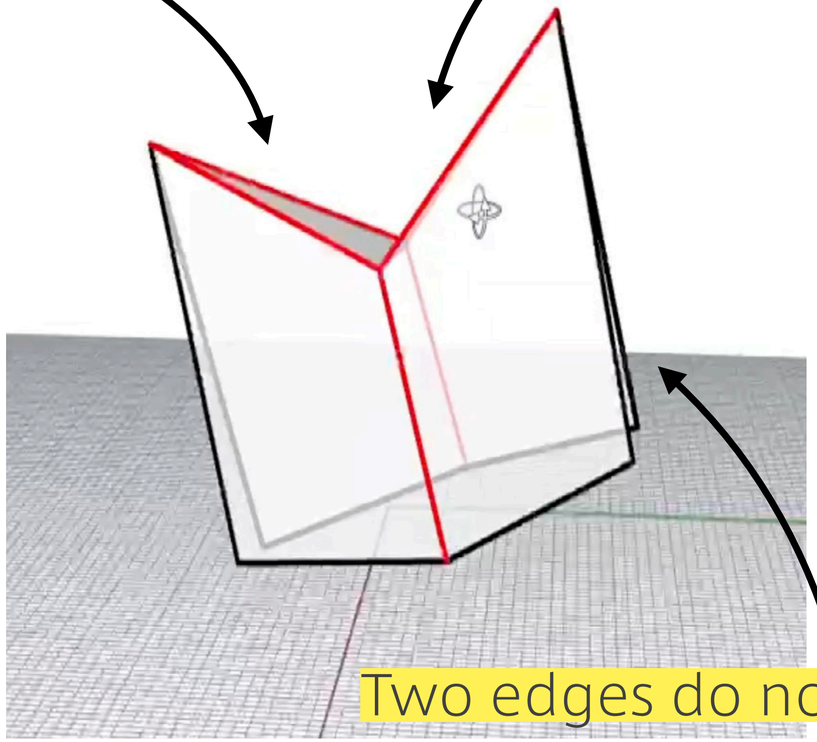
Step 2: Simulation and form-finding

Backrest leans too much

Not symmetry

Seat not horizontal

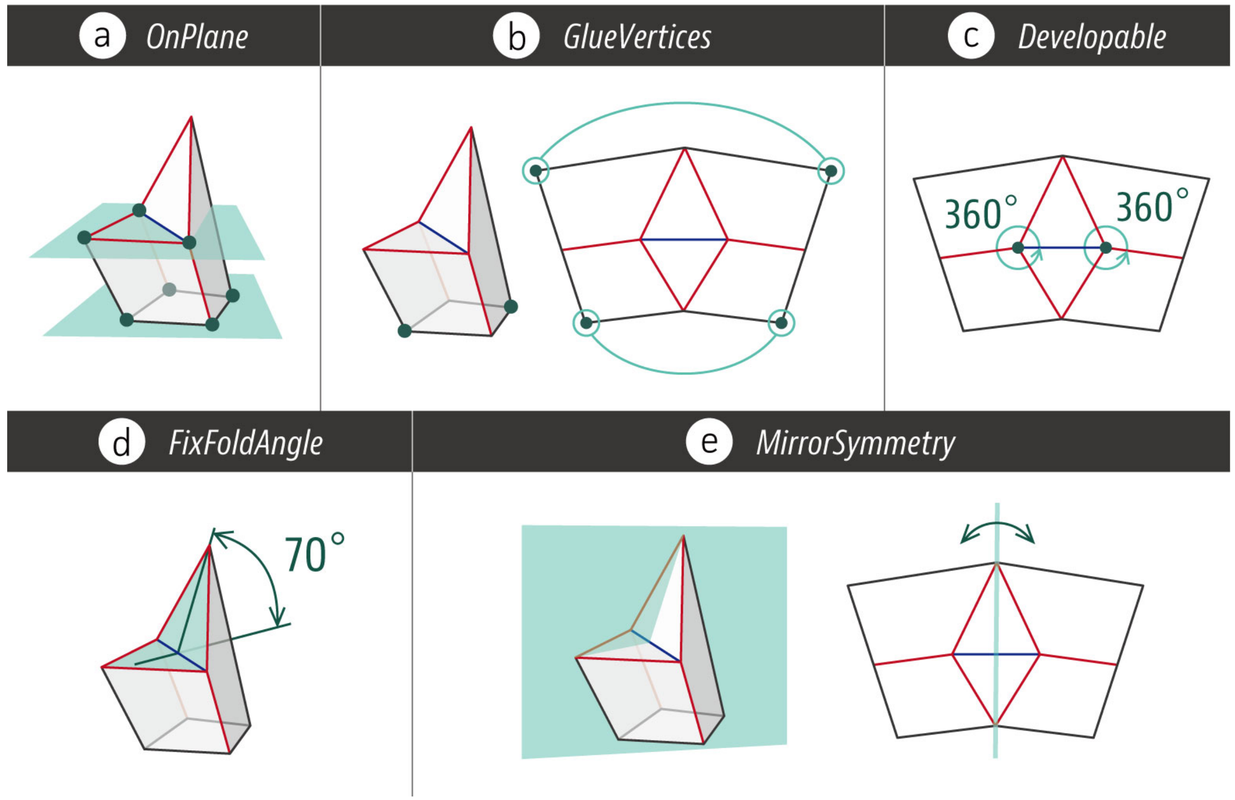




Two edges do not touch each other

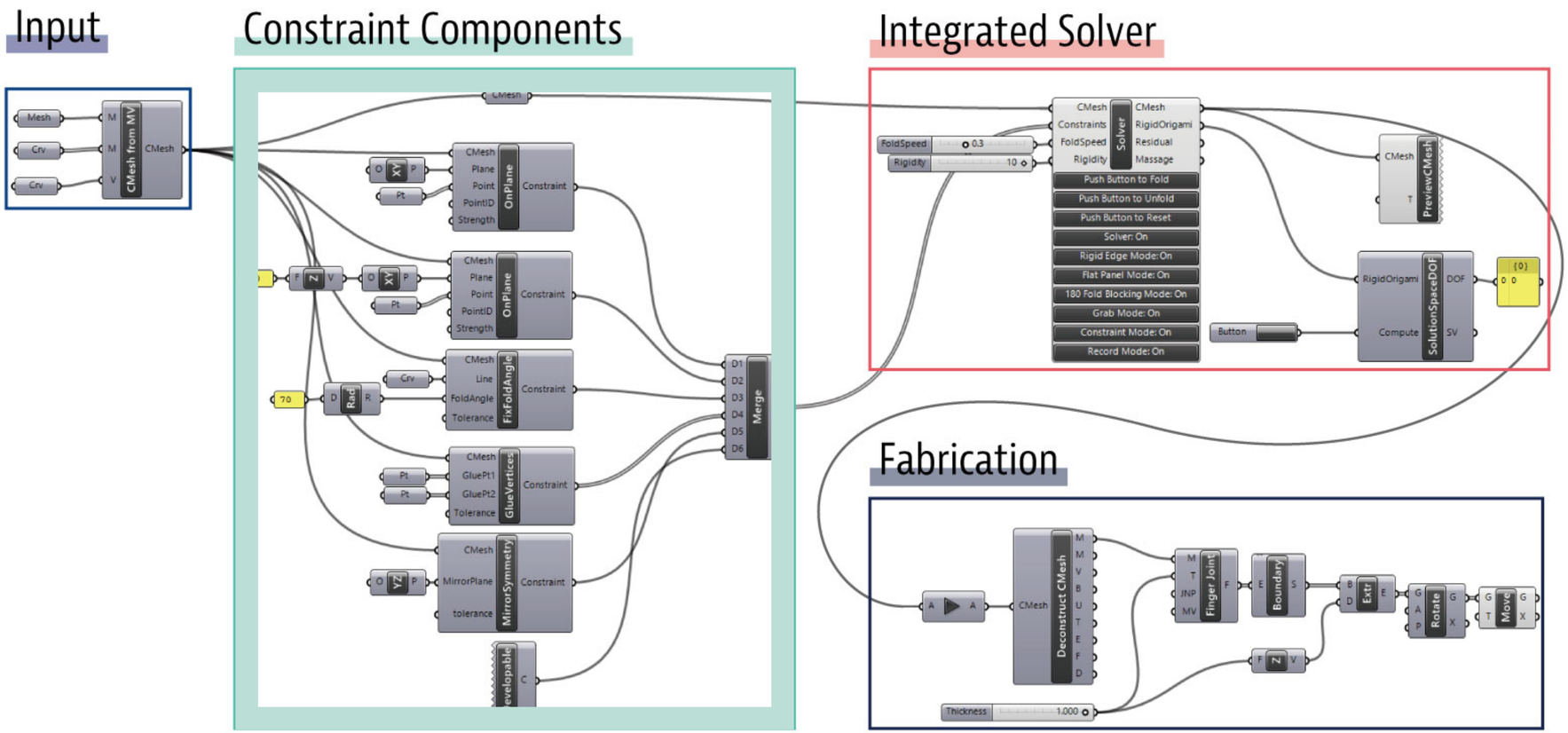
Edges floating from the ground

Step 2: Simulation and form-finding



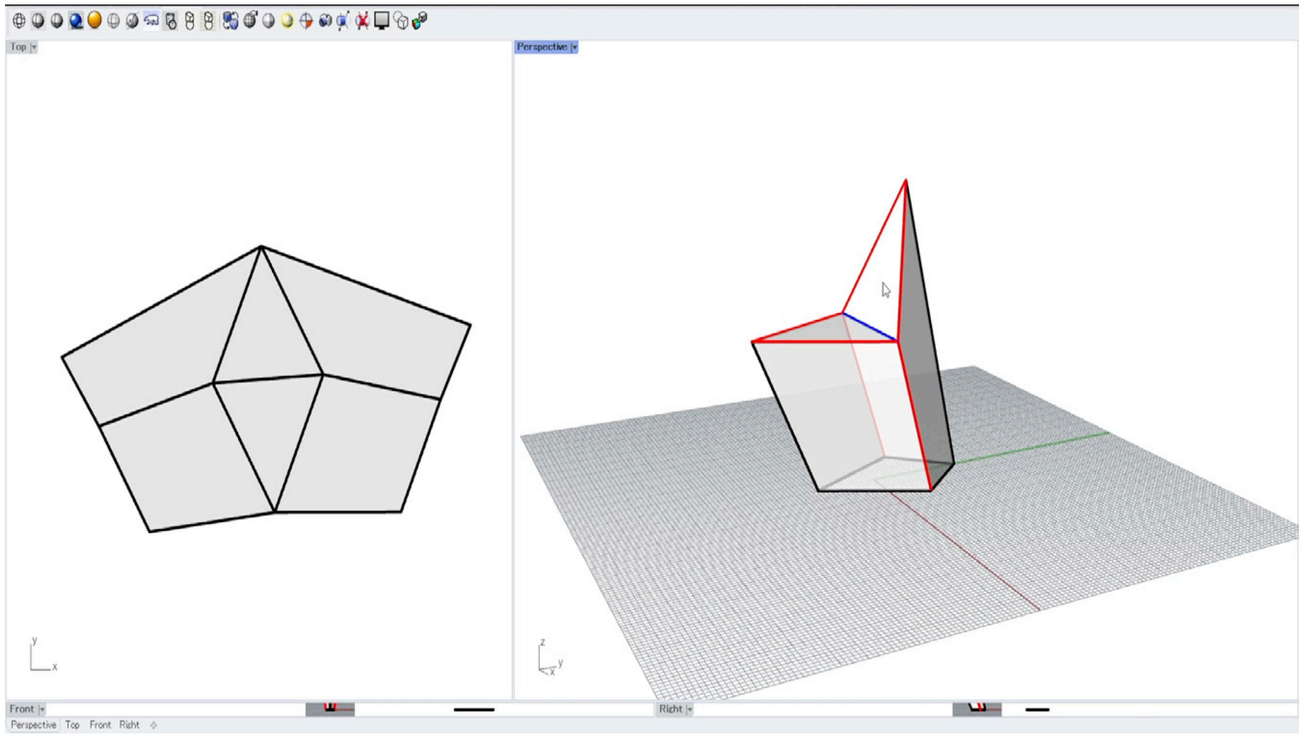
Users put constraint components to solve issues.

Step 2: Simulation and form-finding



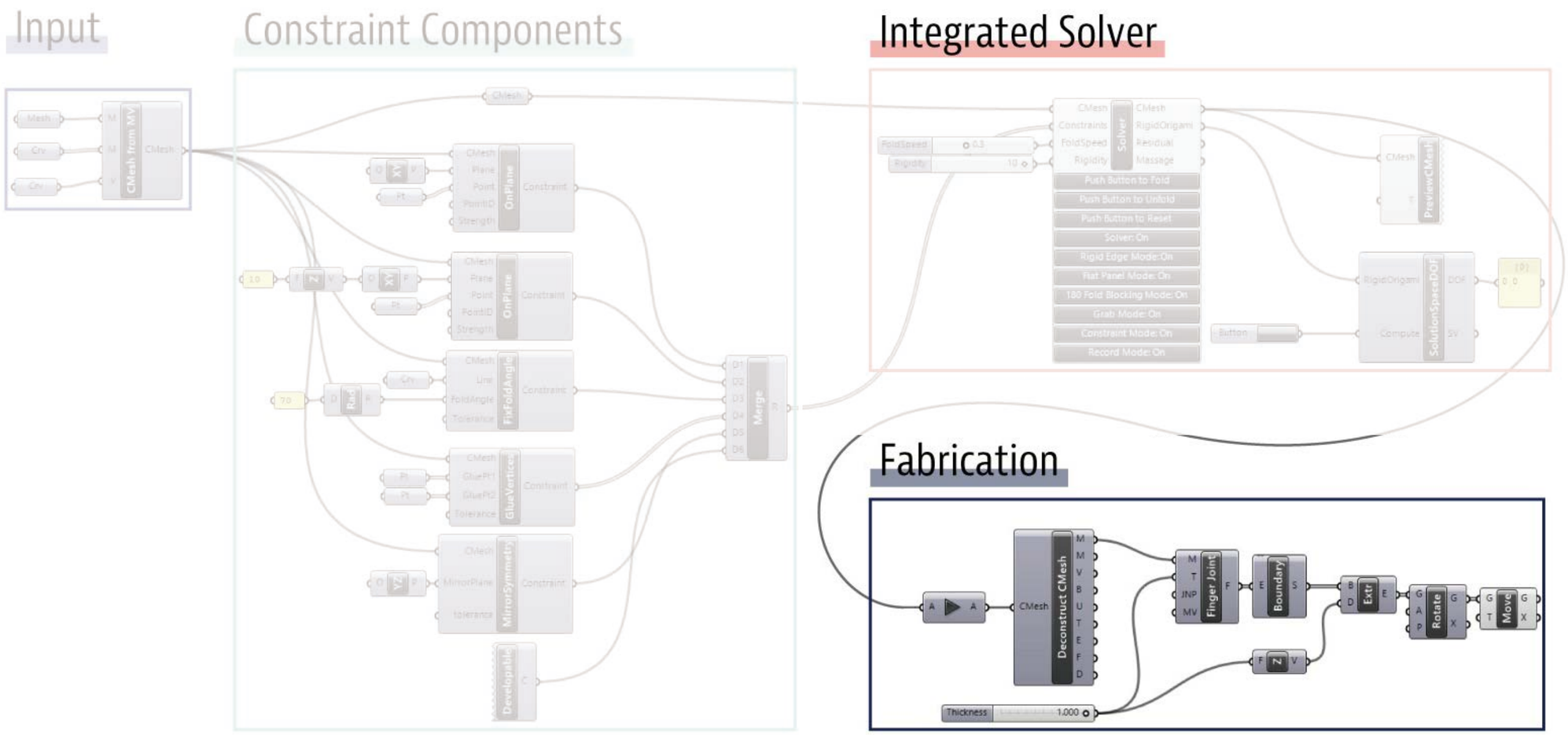
Constraints are connected to a Solver.

Step 2: Simulation and form-finding

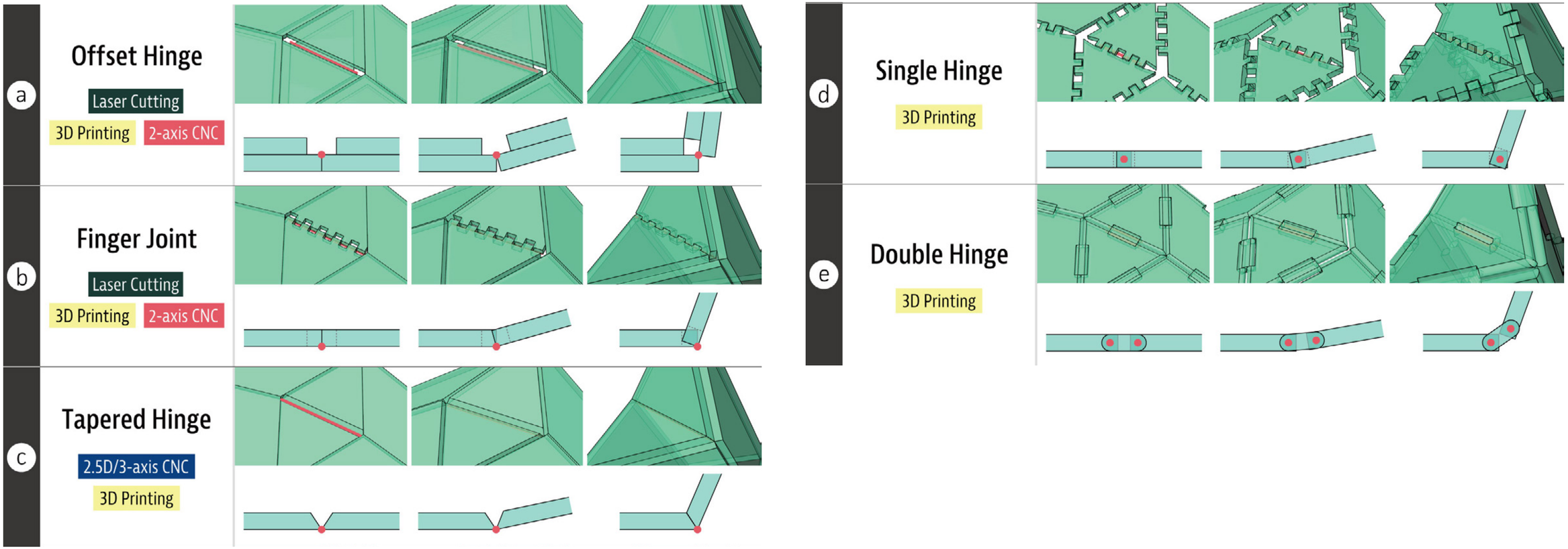


The system **automatically finds a shape satisfying constraints**.
Users can also **manually modify 2D or 3D shapes**, while preserving constraints.

Step 3: Fabrication

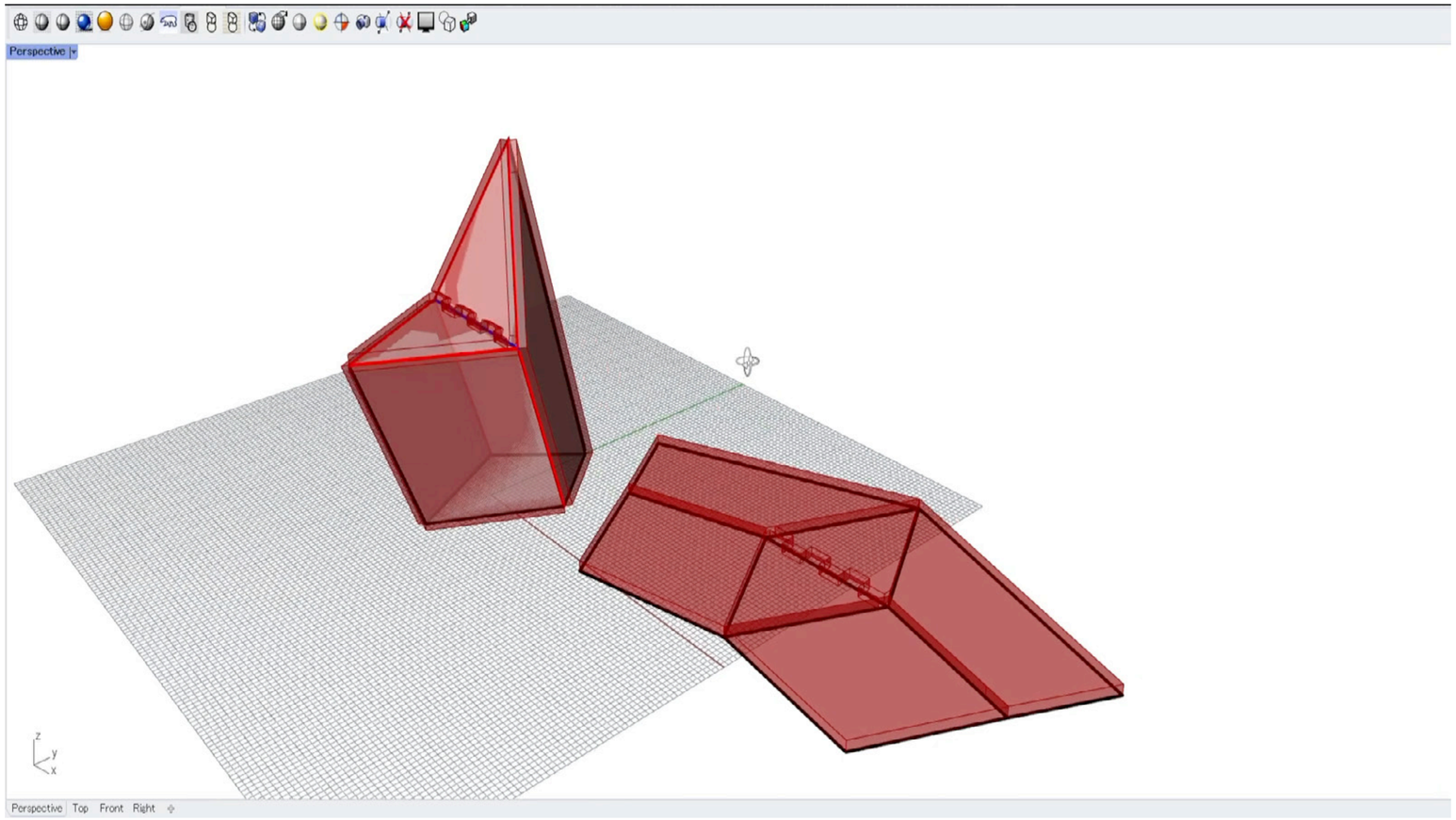


Step 3: Fabrication



The system **assigns hinges considering the thickness, folding angle, and fabrication tool**.

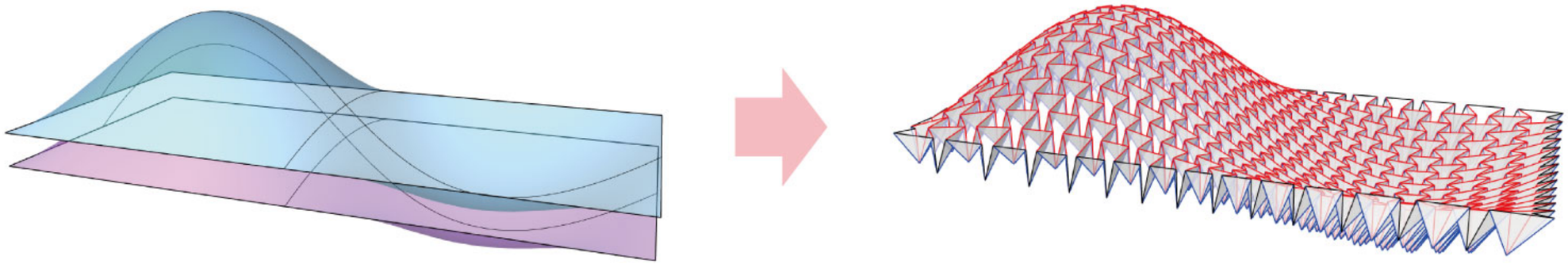
Step 3: Fabrication



Users can try different hinge structures for the same pattern.

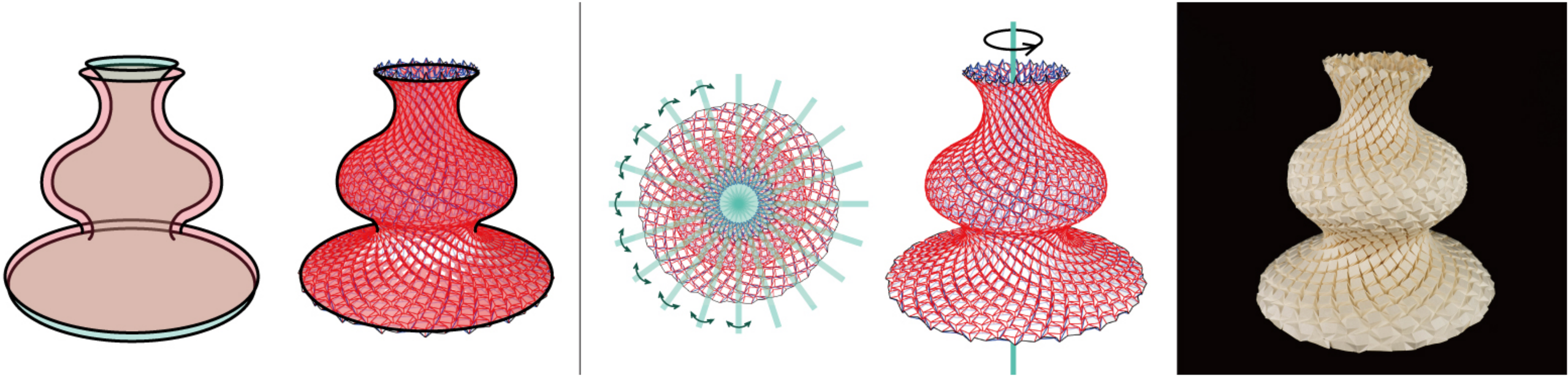
Other Functions

Tessellation between two surfaces



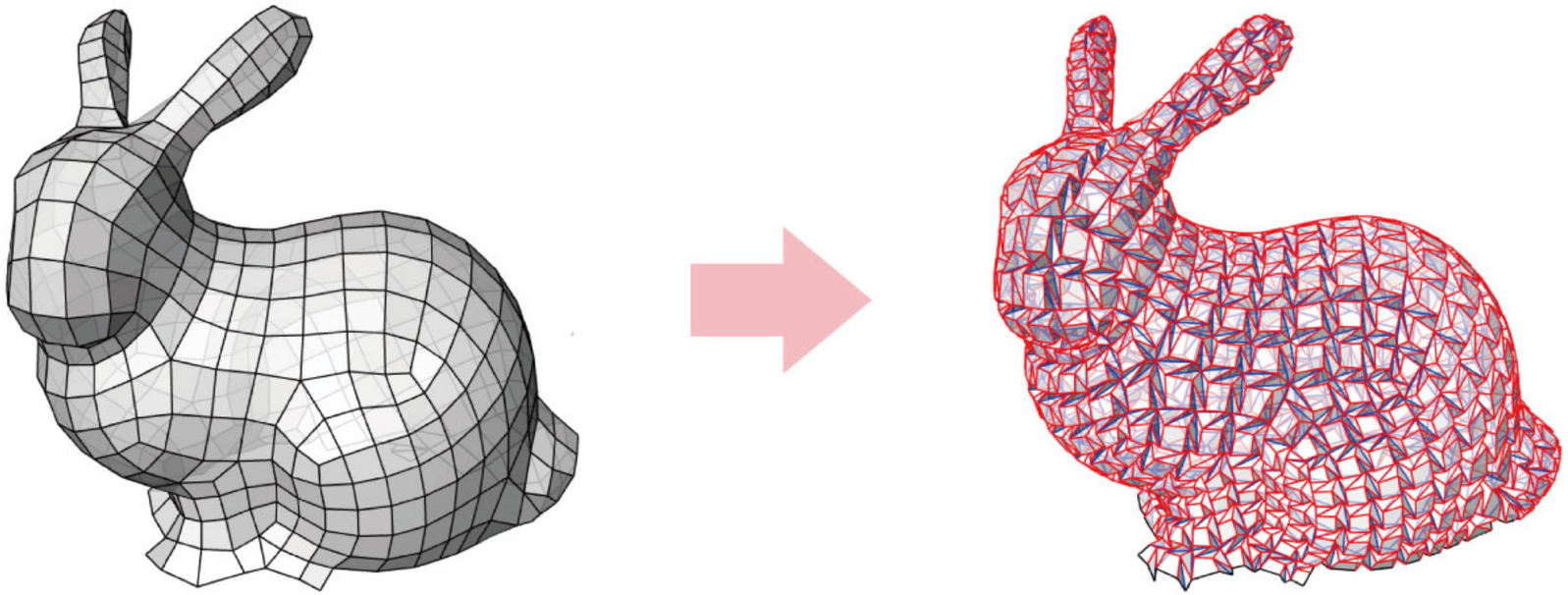
Given **two offset surfaces**, the system generates a pattern between them.

Lampshade



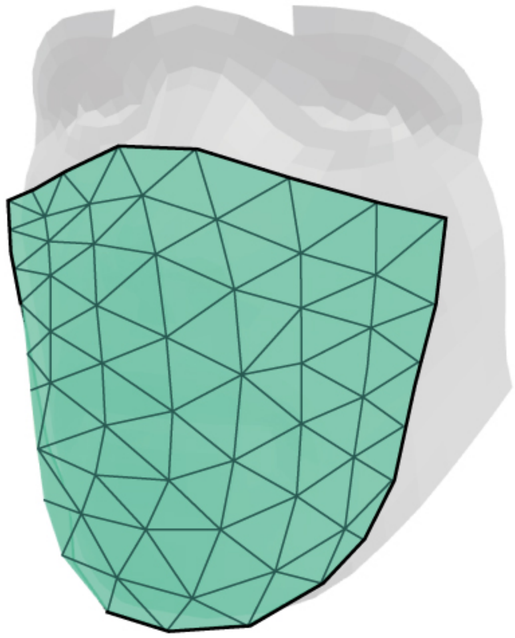
The pattern was **automatically generated from the offset surfaces**.
The shape satisfies **rotational symmetry**.

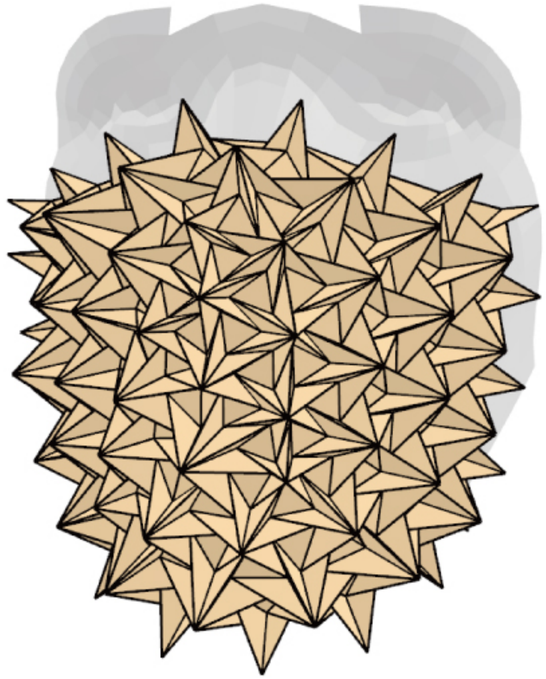
Generalized Ron Resch pattern



Given **an arbitrary polyhedral mesh**, the system generates an approximated pattern.

Mask





The pattern is **automatically generated from a mesh** covering a face.

CRANE

with A-POC ABLE ISSEY MIYAKE

© A-POC ABLE ISSEY MIYAKE

TYPE-V Nature Architects project

© A-POC ABLE ISSEY MIYAKE

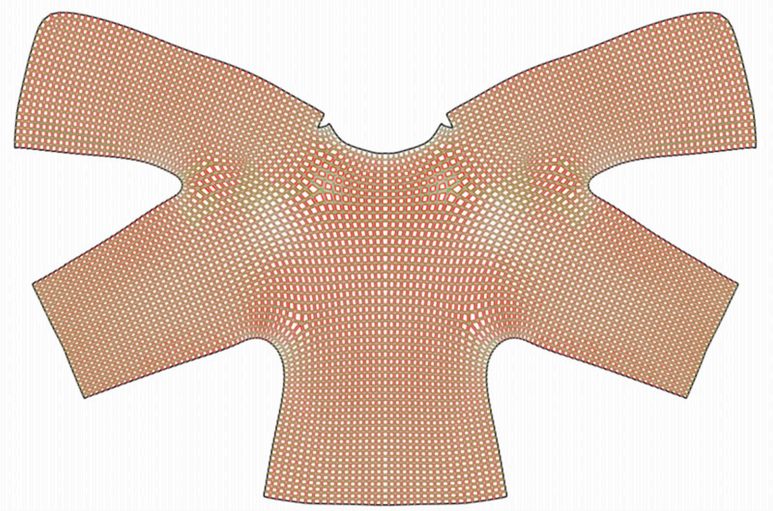
April 2023, in Milan, Italy

Salone del Mobile Milano 2023 at ISSEY MIYAKE / MILAN, © A-POC ABLE ISSEY MIYAKE

Salone del Mobile Milano 2023 at ISSEY MIYAKE / MILAN, © A-POC ABLE ISSEY MIYAKE

Salone del Mobile Milano 2023 at ISSEY MIYAKE / MILAN, © A-POC ABLE ISSEY MIYAKE

Conventional design procedure
(Forward design)



2D

3D

The procedure enabled by Crane
(Inverse design)

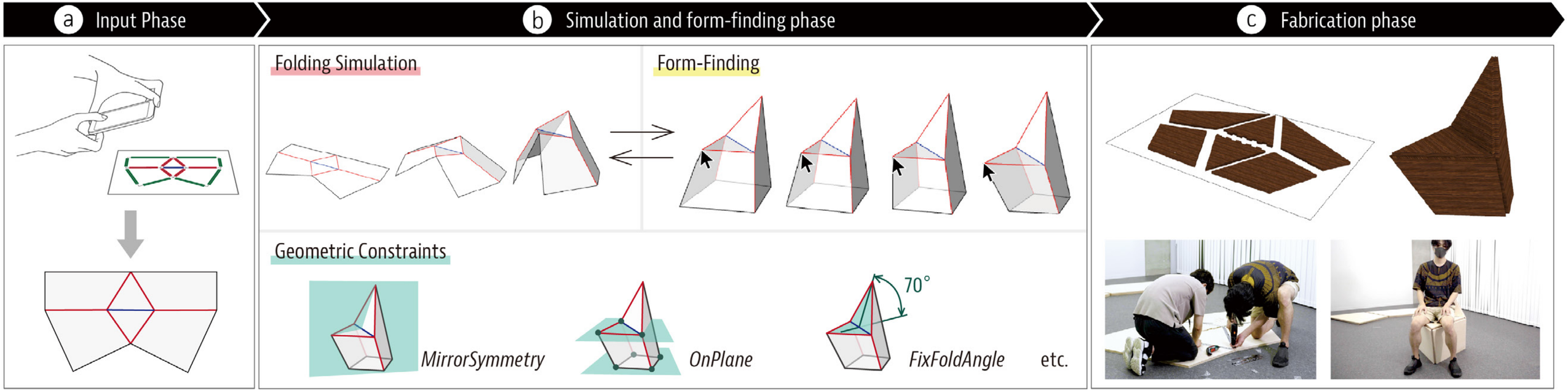
Salone del Mobile Milano 2023 at ISSEY MIYAKE / MILAN, © A-POC ABLE ISSEY MIYAKE

Salone del Mobile Milano 2023 at ISSEY MIYAKE / MILAN, © A-POC ABLE ISSEY MIYAKE

There are many fabrication papers published in CHI every year,

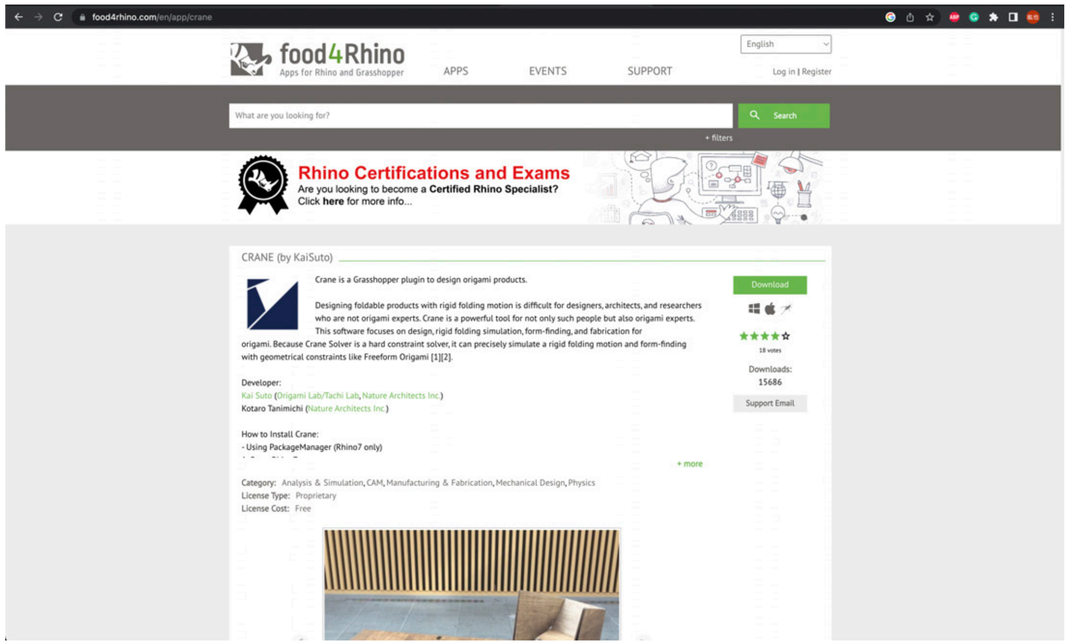
but we are proud of our paper **applied to the REAL design and industry.**

Conclusions



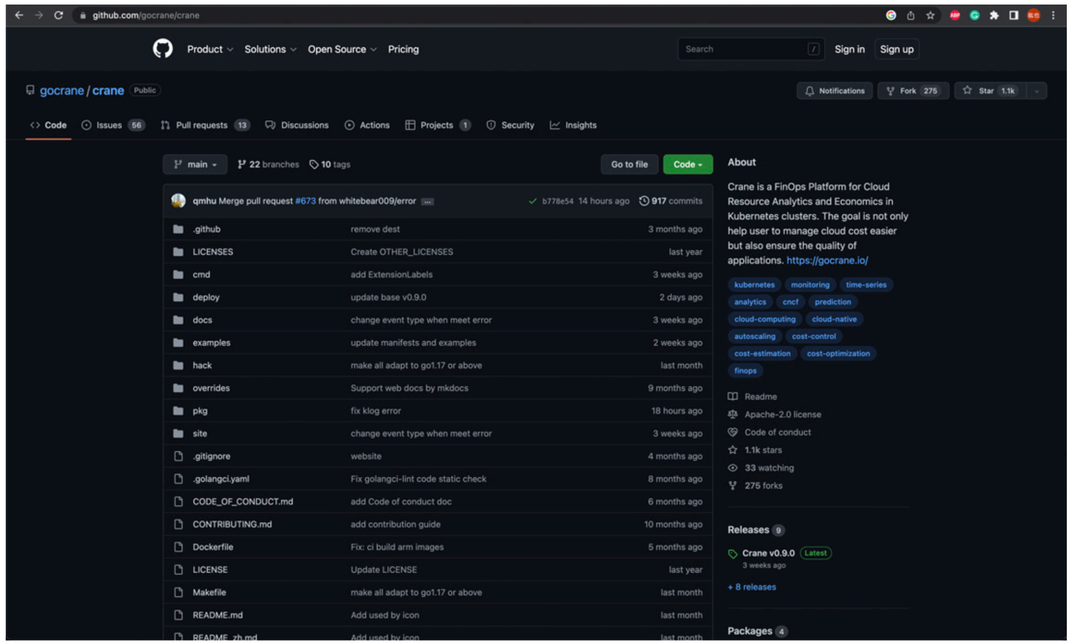
Crane is a **seamless design platform** for design and fabrication of origami product allowing for **input, simulation, form-finding, and panel thickening**.

Crane is open-source



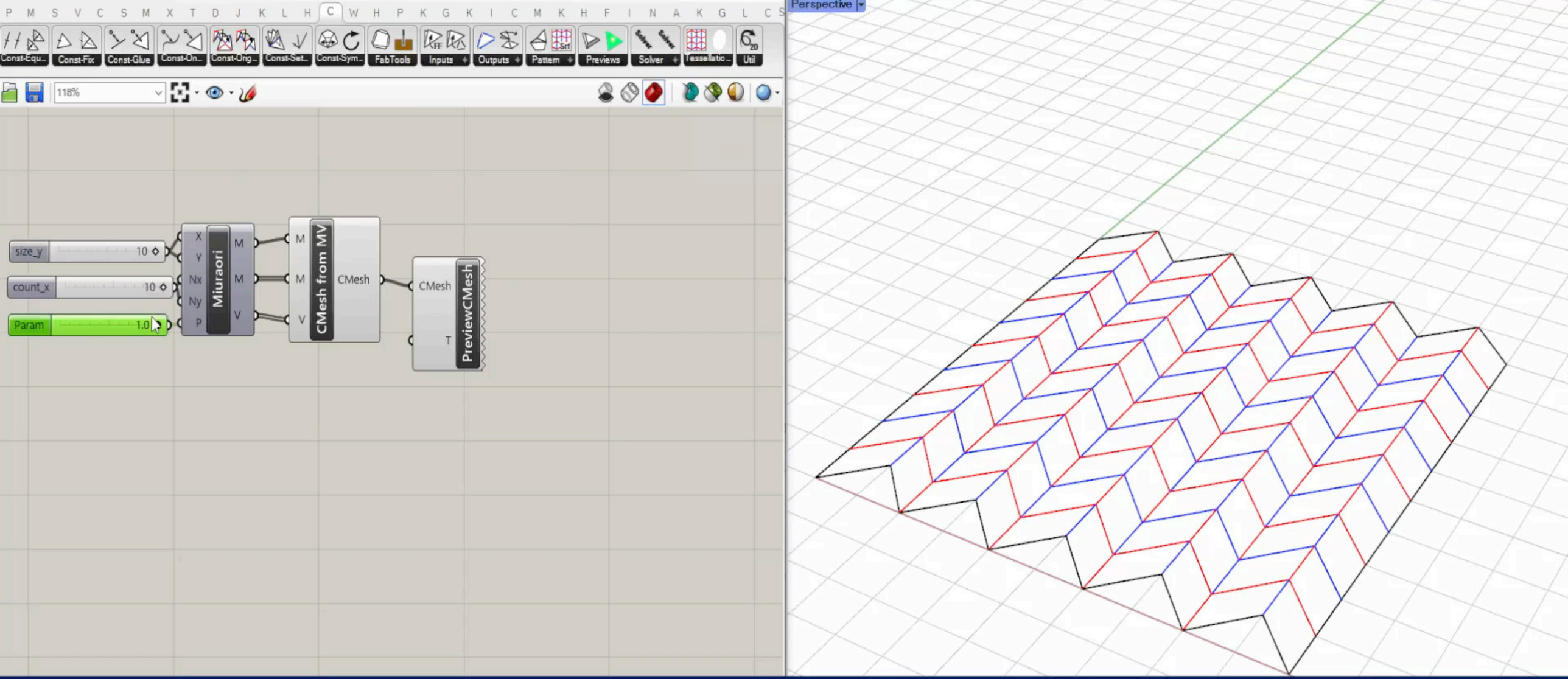
Food4Rhino

https://www.food4rhino.com/en/app/crane



GitHub

https://github.com/gocrane/crane



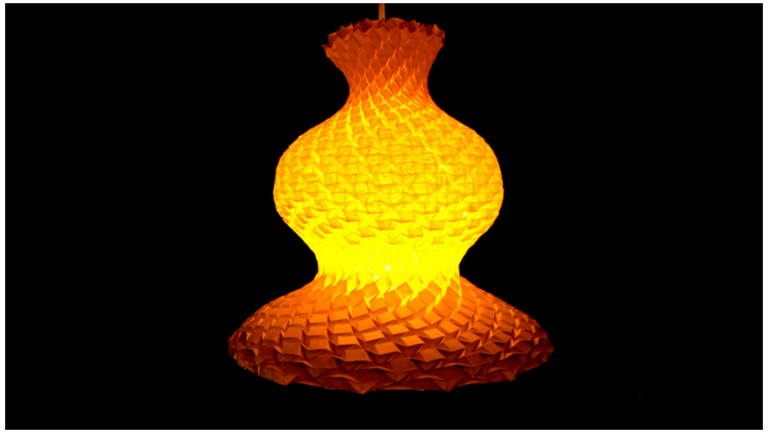
CRANE

An Integrated Computational Design Platform for Functional, Foldable, and Fabricable Origami Products

Kai Suto, Yuta Noma, Kotaro Tanimichi, Koya Narumi, Tomohiro Tachi
The University of Tokyo, Nature Architects, Inc.

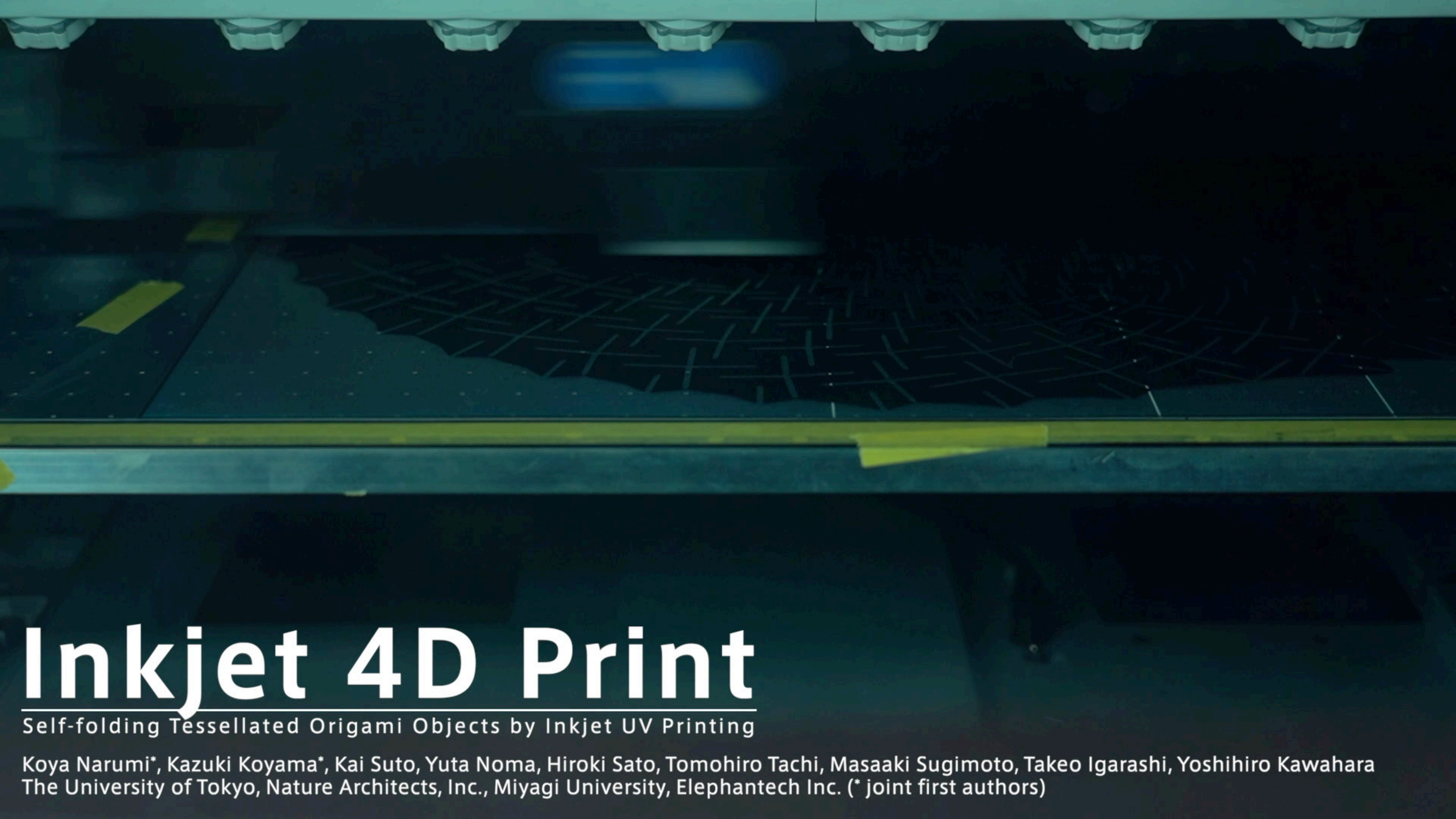
Origami-inspired Computational Fabrication

Pop-up Print
ACM UIST 2020



Crane
ACM TOCHI (CHI) 2023

Inkjet 4D Print
ACM TOG (SIGGRAPH) 2023

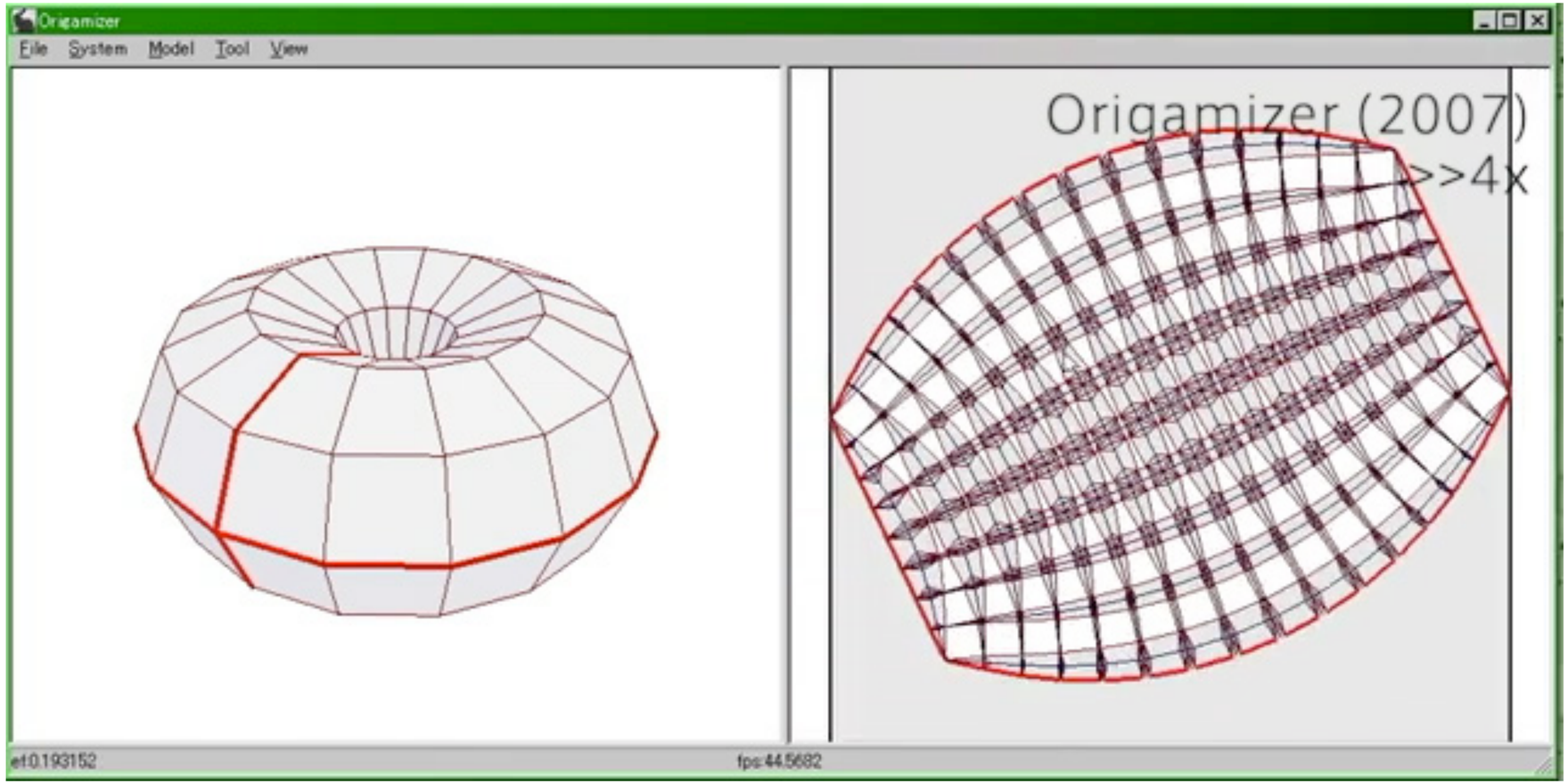


Inkjet 4D Print

Self-folding Tessellated Origami Objects by Inkjet UV Printing

Koya Narumi*, Kazuki Koyama*, Kai Suto, Yuta Noma, Hiroki Sato, Tomohiro Tachi, Masaaki Sugimoto, Takeo Igarashi, Yoshihiro Kawahara
The University of Tokyo, Nature Architects, Inc., Miyagi University, Elephantech Inc. (* joint first authors)

Any Polyhedron is Foldable

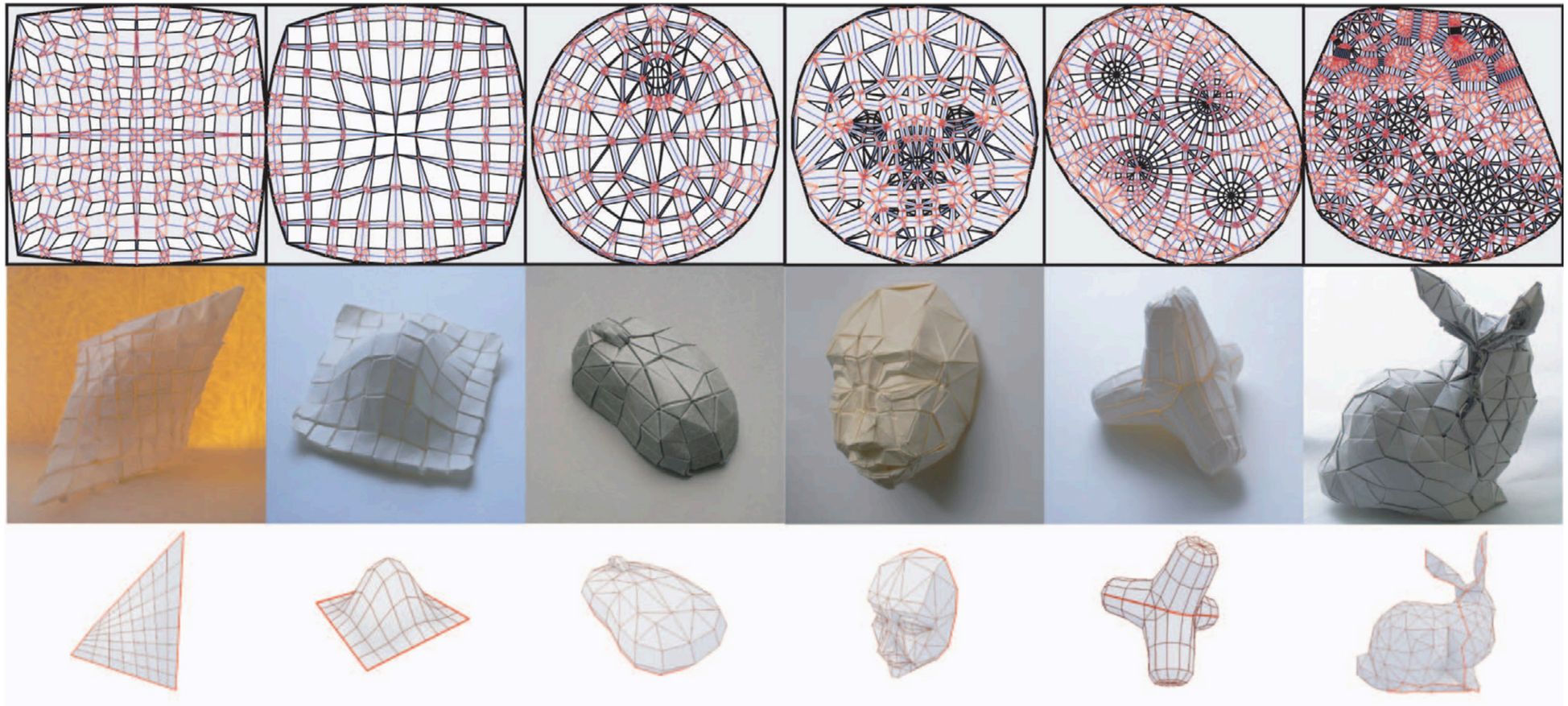


[1]

In 2017, Demaine and Tachi proved that **any polyhedron is foldable from a sheet of paper** [2].

[1] Tachi, Origamizing Polyhedral Surfaces, TVCG2010. [2] Demaine and Tachi, Origamizer, SoCG2017.

Any Polyhedron is Foldable

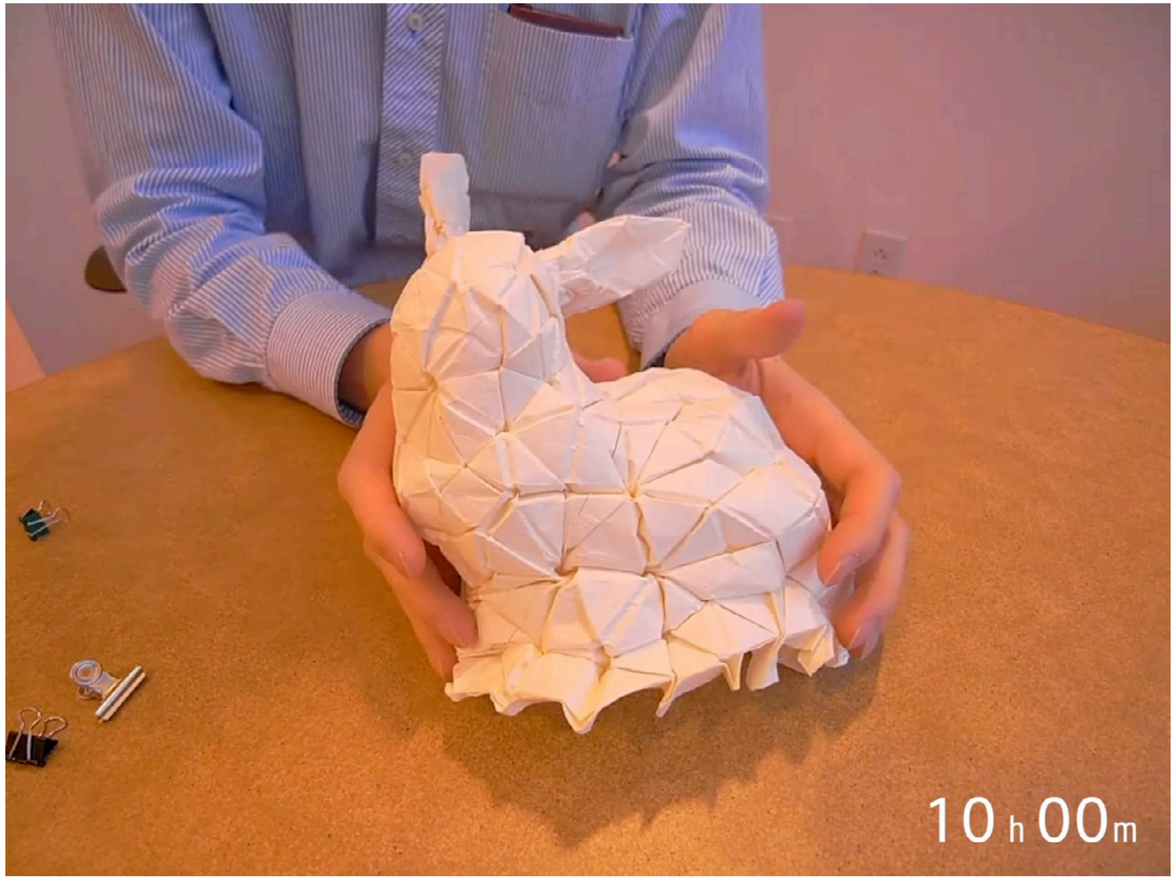


[1]

In 2017, Demaine and Tachi proved that **any polyhedron is foldable from a sheet of paper** [2].

[1] Tachi, Origamizing Polyhedral Surfaces, TVCG2010. [2] Demaine and Tachi, Origamizer, SoCG2017.

But Origami Takes **So Long** Time

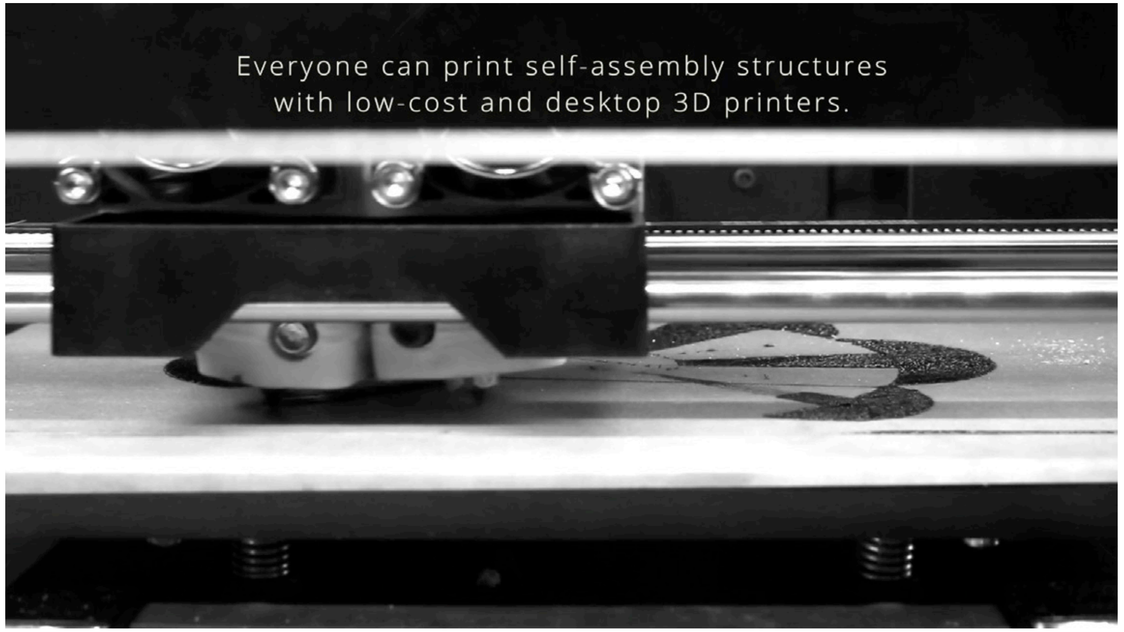


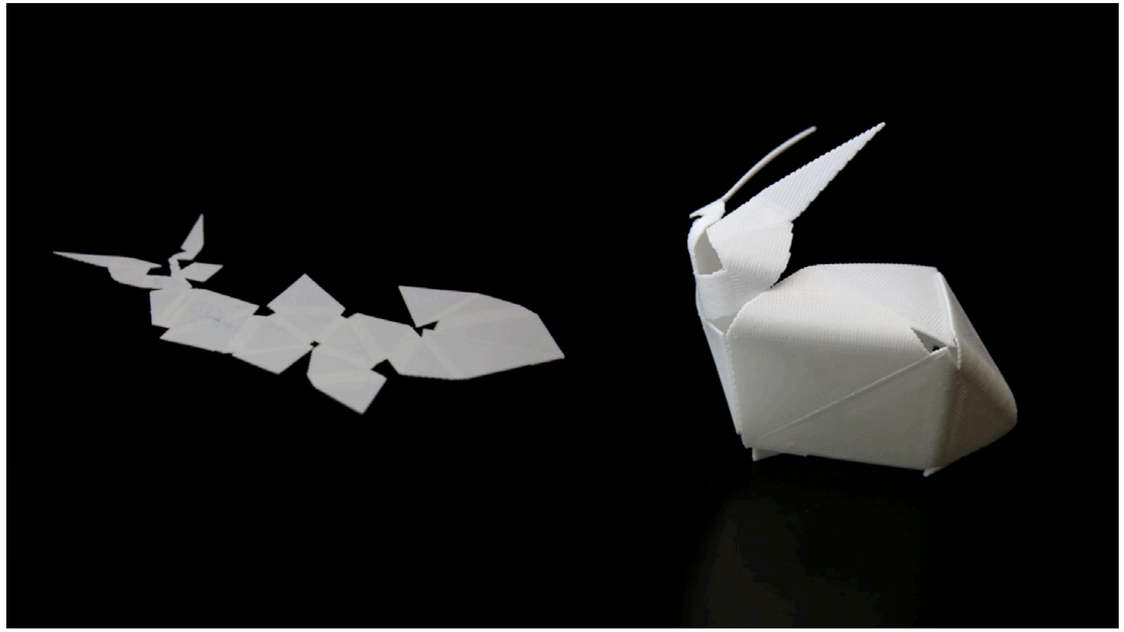
[1]

Software generates the pattern in seconds, but **manual folding sometimes takes tens of hours**.

[1] Tachi, How To Fold a Bunny, 2009. https://youtu.be/GAnW-KU2yn4

Possible Solution: 4D Printing for Self-folding



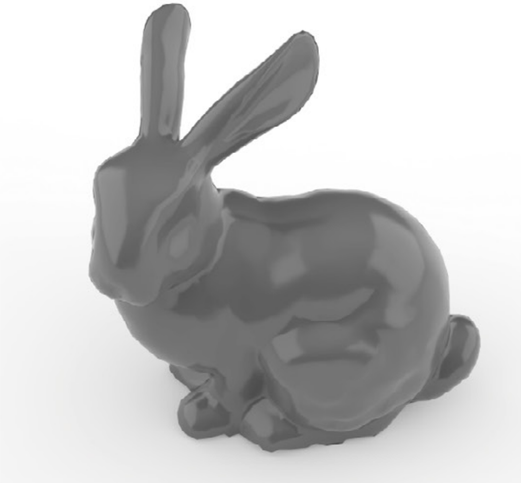


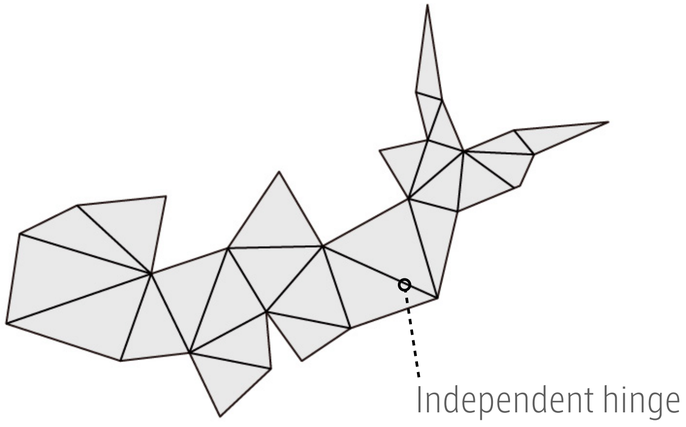
[1]

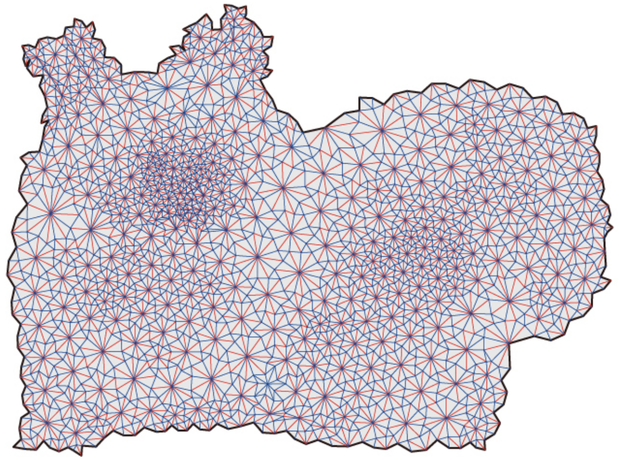
4D printing achieves **a self-folded 3D shape by time-dependent shape change (+1D)**.

[1] An et al., Thermorph, CHI2018.

Prior 4D Printing is **Not Enough** for Origami

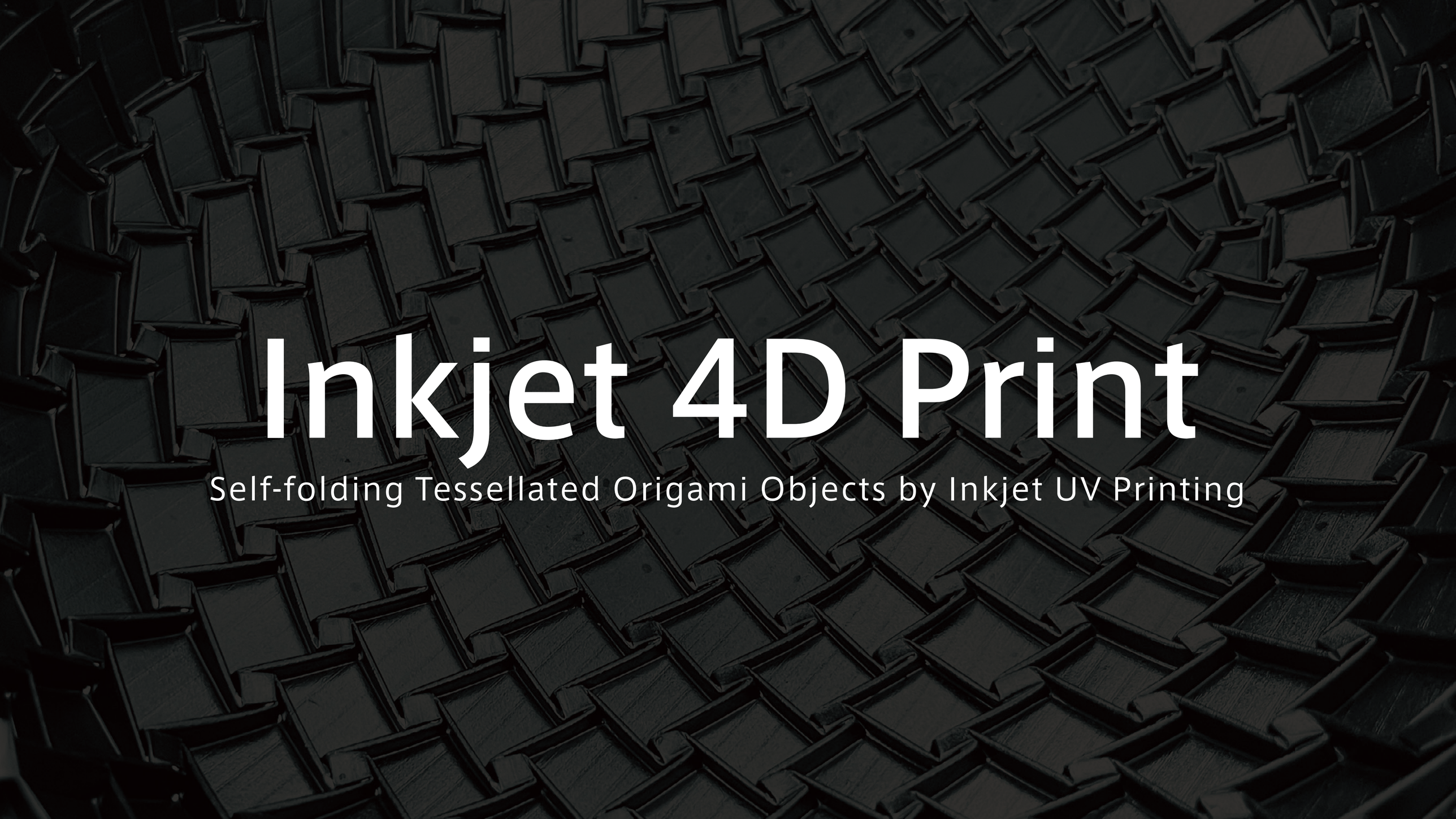






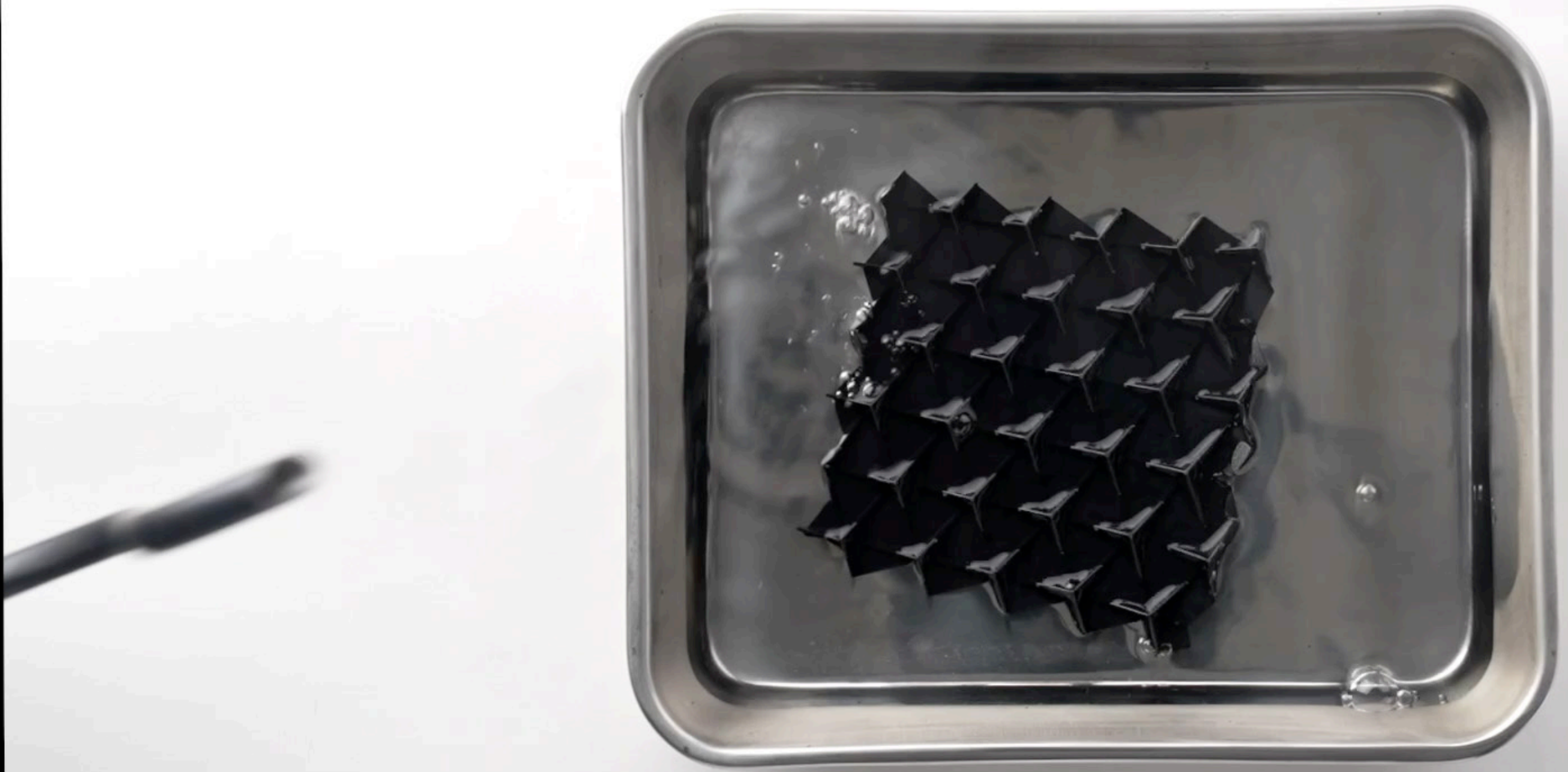
	Prior 4D Printing [1]	What origami researchers want
Number of facets	**26**	**4299**
Hinges	**Independent**	**Dependent**
Hardware	FDM 3D printer	???

[1] An et al., Thermorph, CHI2018.

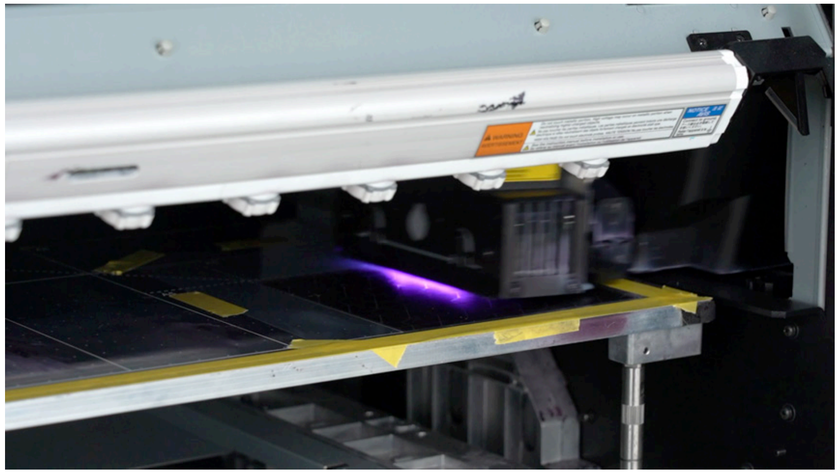


Inkjet 4D Print

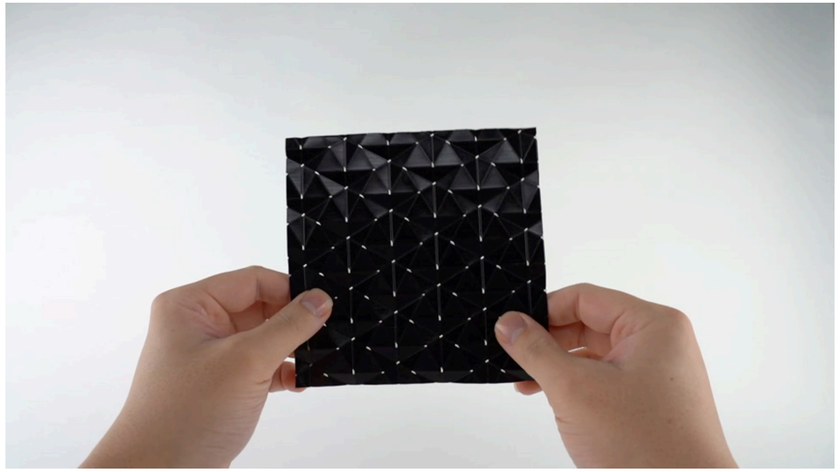
Self-folding Tessellated Origami Objects by Inkjet UV Printing



Inkjet 4D Print: Overview



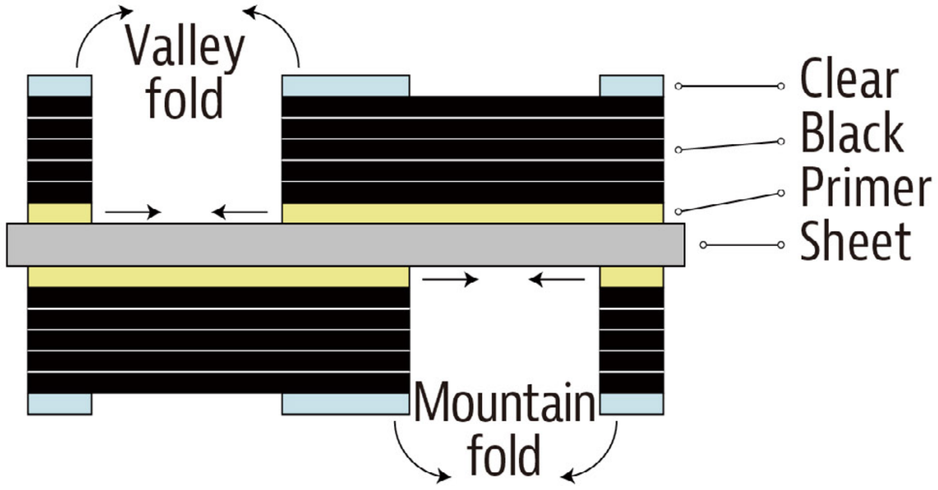
Inkjet Printing
by commercialized UV printer



Heat-shrinkable sheet + UV Ink
with origami patterns

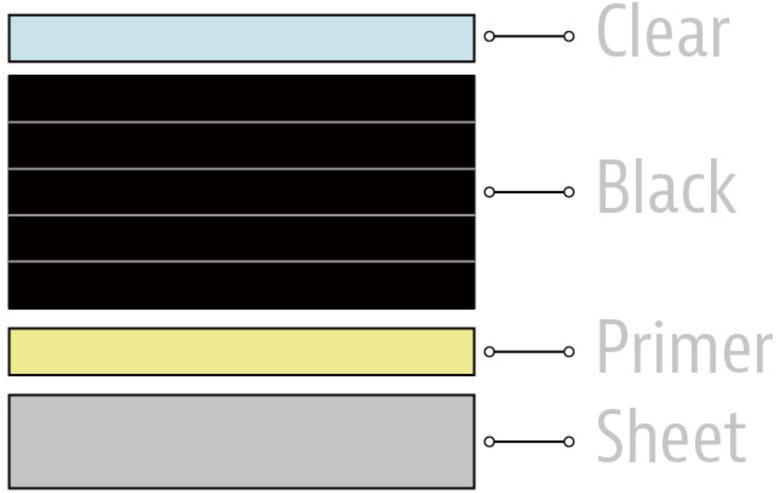
Self-folding
by 70 ℃ heat

Principle



Shrinkage of the heat-shrinkable sheet is constrained by the black ink layers.
By changing the gap width, **folding angle is linearly controllable**.

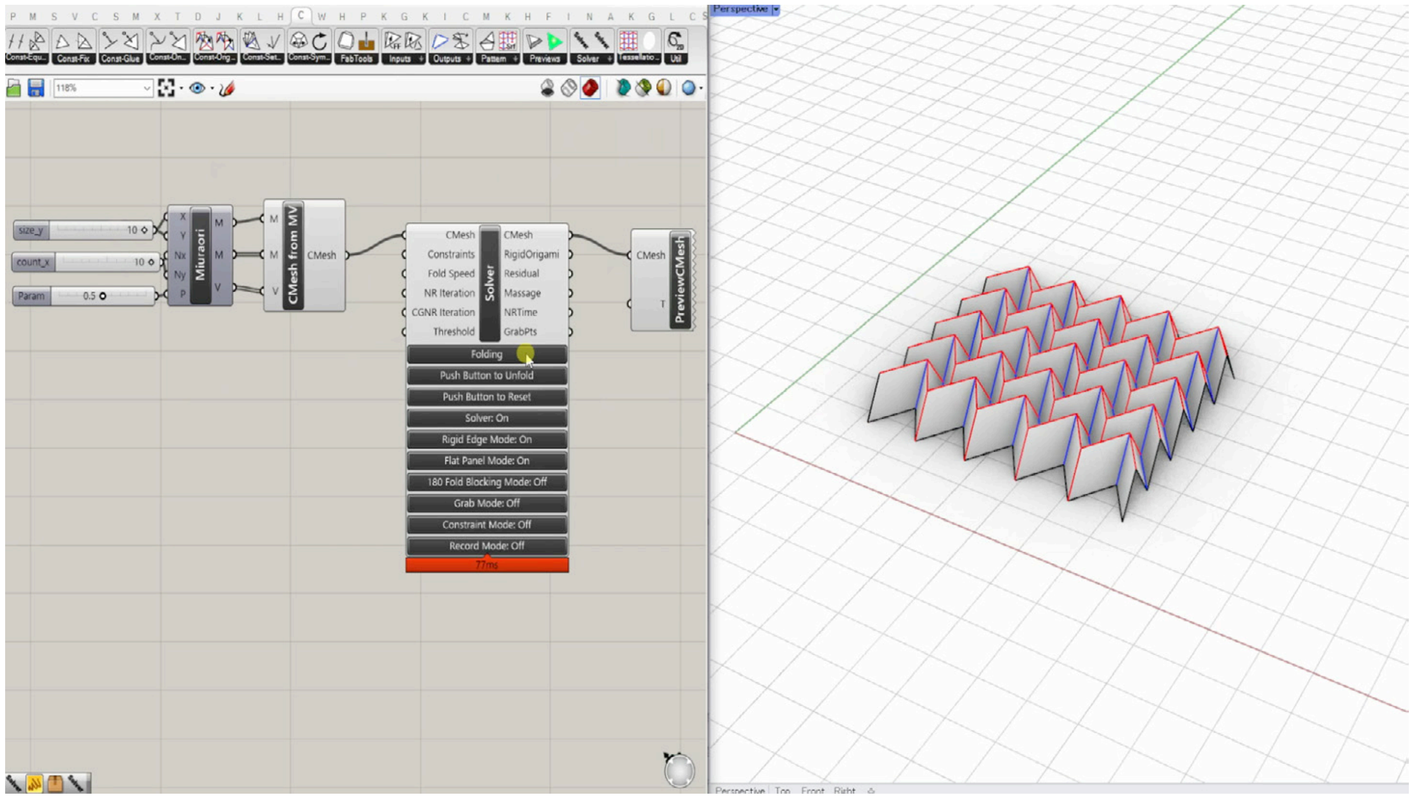
Color



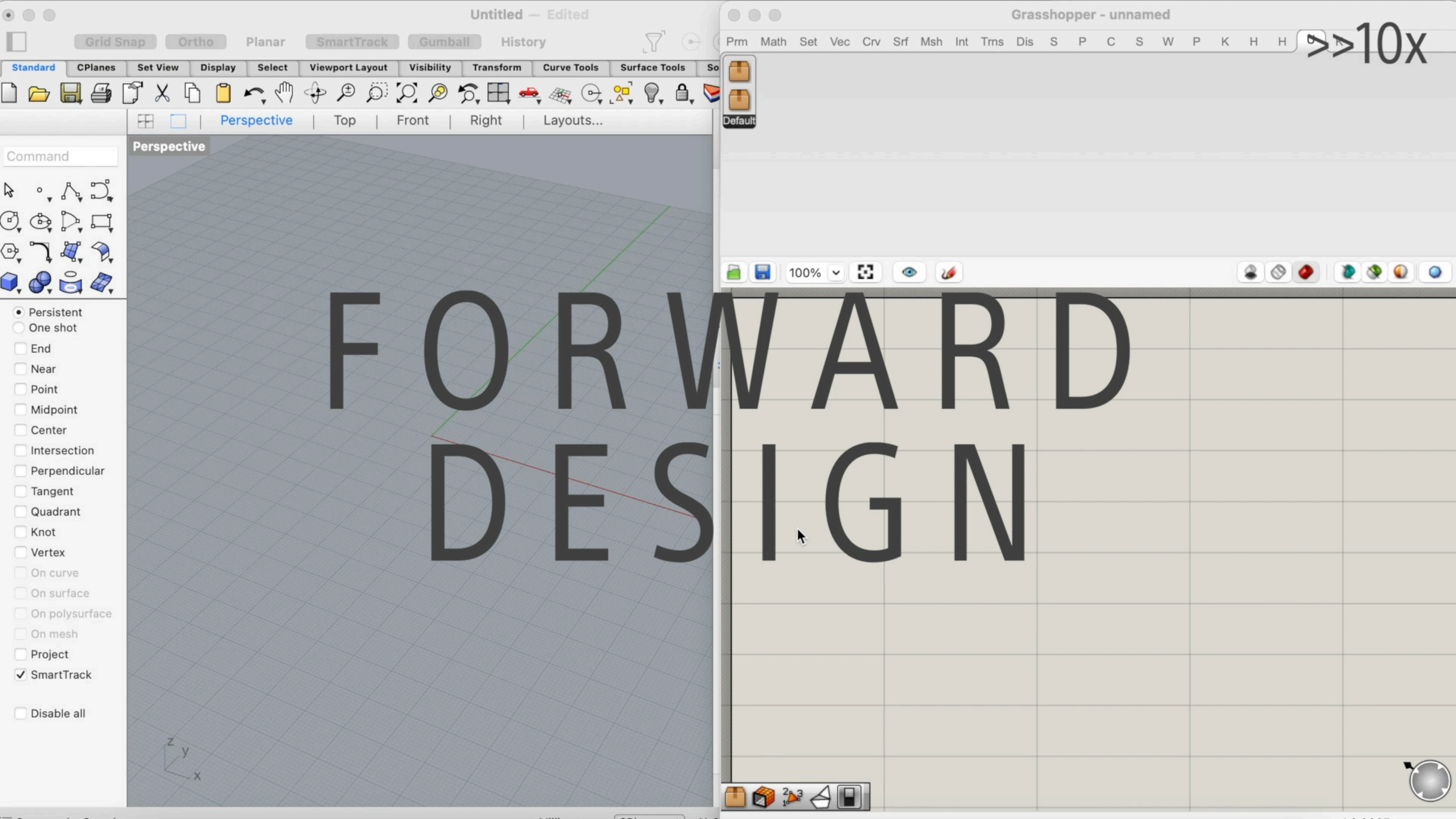
We can achieve **colored texture** as well as shape in one process.

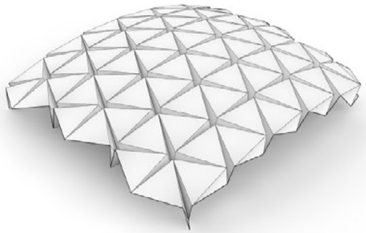
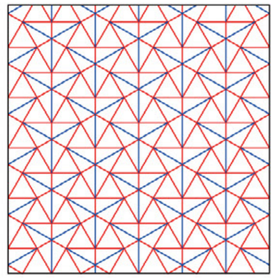
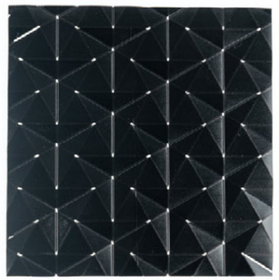
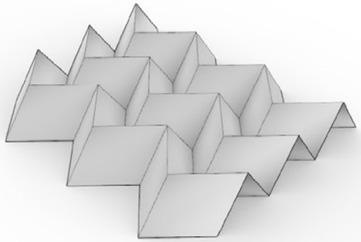
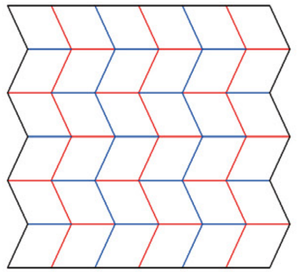
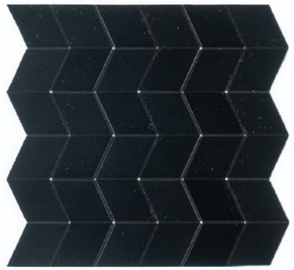
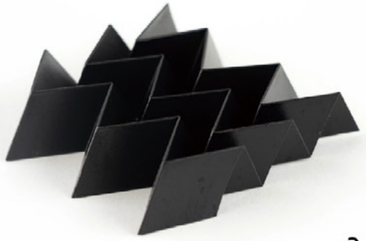
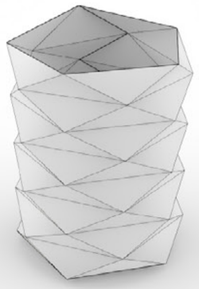
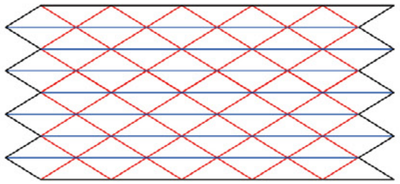
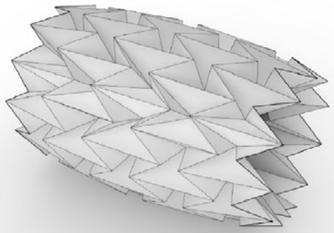
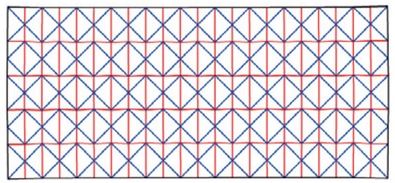
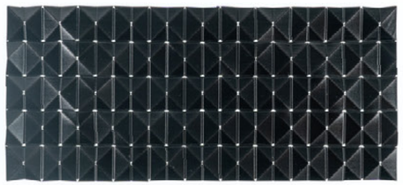
Software & Design Examples

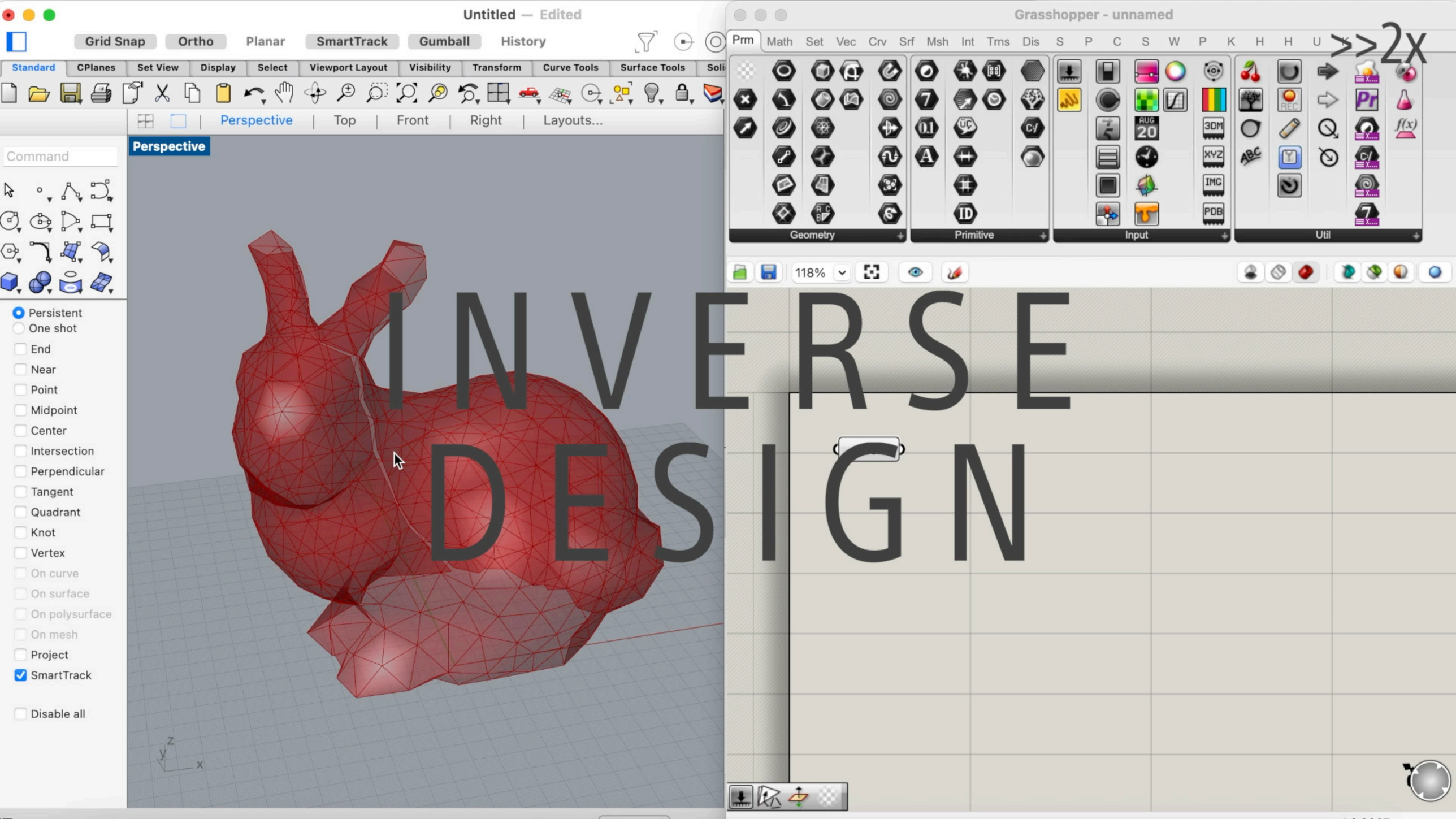
Software Overview

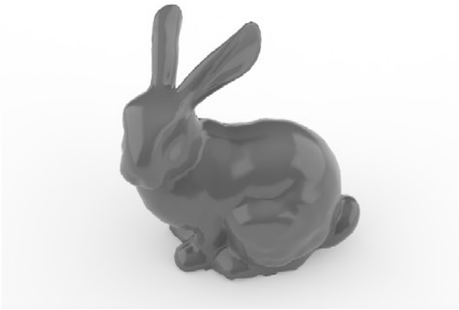
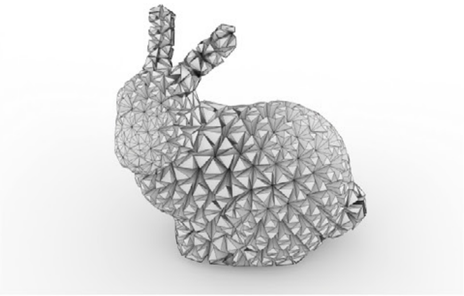
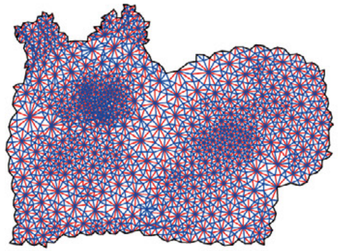
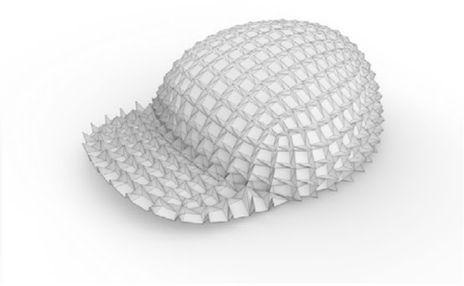
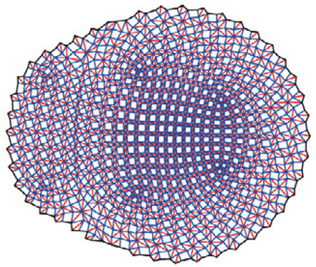
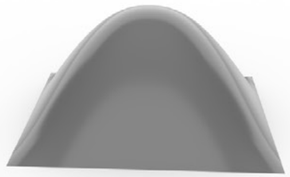
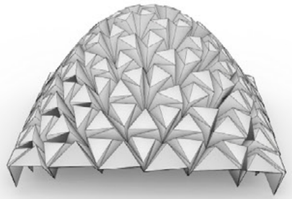
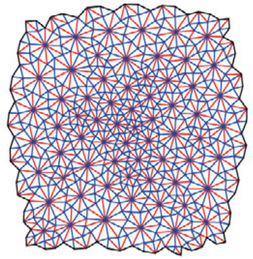
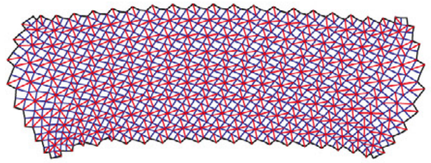


Our GUI is implemented on Rhino/Grasshopper,
with **a visual programming environment and a CAD visualizer**.


Untitled — Edited
Grid Snap
Ortho
Planar
SmartTrack
Gumball
History
Standard
CPlanes
Set View
Display
Select
Viewport Layout
Visibility
Transform
Curve Tools
Surface Tools
Perspective
Top
Front
Right
Layouts...
Command
Persistent
One shot
End
Near
Point
Midpoint
Center
Intersection
Perpendicular
Tangent
Quadrant
Knot
Vertex
On curve
On surface
On polysurface
On mesh
Project
SmartTrack
Disable all
Grasshopper - unnamed
Prm Math Set Vec Crv Srf Msh Int Trns Dis S P C S W P K H H
>>10x
Default
100%
FORWARD
DESIGN

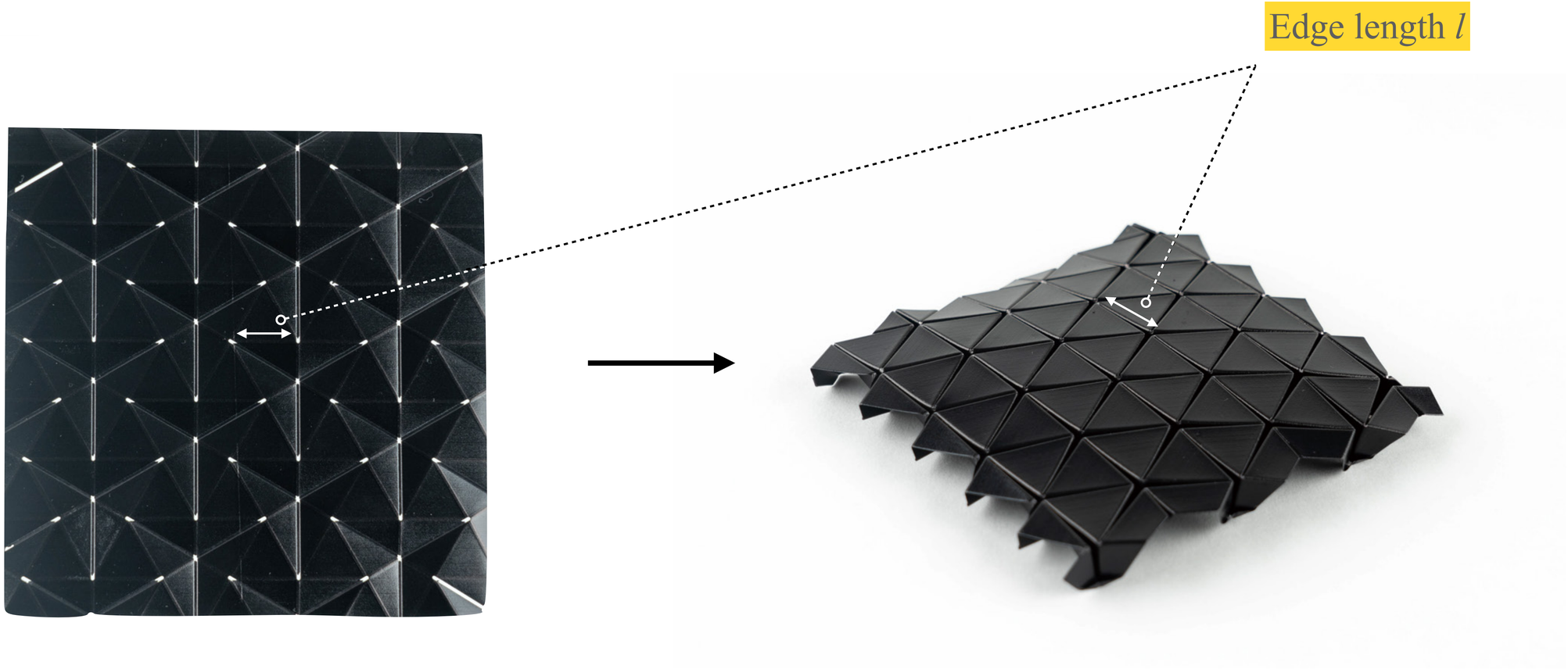
Name 2D origami size	3D model	2D model	2D photo	3D photo
Ron Resch pattern 267 facets 130 mm x 130mm				3 cm
Miura folding 36 facets 140 mm x 130mm				 2 cm
Yoshimura pattern 80 facets 108 mm x 64mm				2 cm
Waterbomb pattern 330 facets 280 mm x 130 mm				2 cm


Untitled — Edited
Grid Snap
Ortho
Planar
SmartTrack
Gumball
History
Standard
CPlanes
Set View
Display
Select
Viewport Layout
Visibility
Transform
Curve Tools
Surface Tools
Perspective
Top
Front
Right
Layouts...
Command
Persistent
One shot
End
Near
Point
Midpoint
Center
Intersection
Perpendicular
Tangent
Quadrant
Knot
Vertex
On curve
On surface
On polysurface
On mesh
Project
SmartTrack
Disable all
Grasshopper - unnamed
Prm
Math
Set
Vec
Crv
Srf
Msh
Int
Trns
Dis
Geometry
Primitive
Input
Util
118%
>>2x
INVERSE
DESIGN

Name 2D origami size	3D model (input)	3D model (origami)	2D model	2D photo	3D photo
Bunny 4299 facets 610 mm x 420 mm					
Cap 3426 facets 474 mm x 402 mm					
Mountain 1045 facets 271 x 286 mm					
Torus 1770 facets 212 mm x 491 mm					

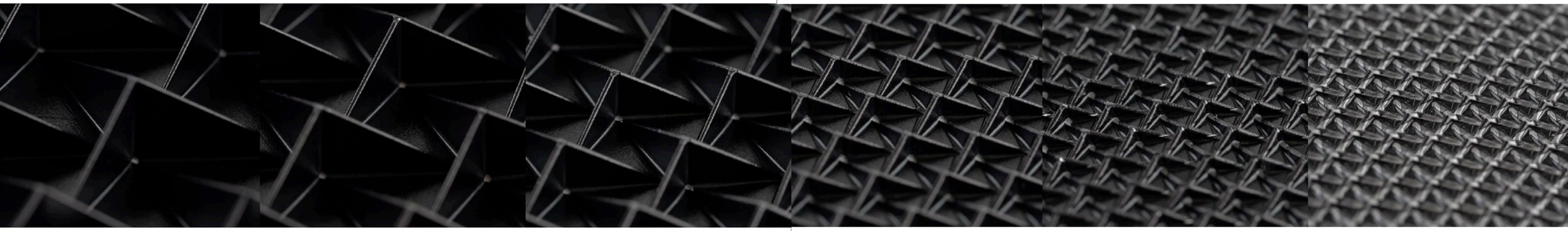
Evaluation

Resolution



We defined the resolution by the edge length l of Ron Resch patterns.
Then, **the practical folding resolution was l = 3.0 mm**.

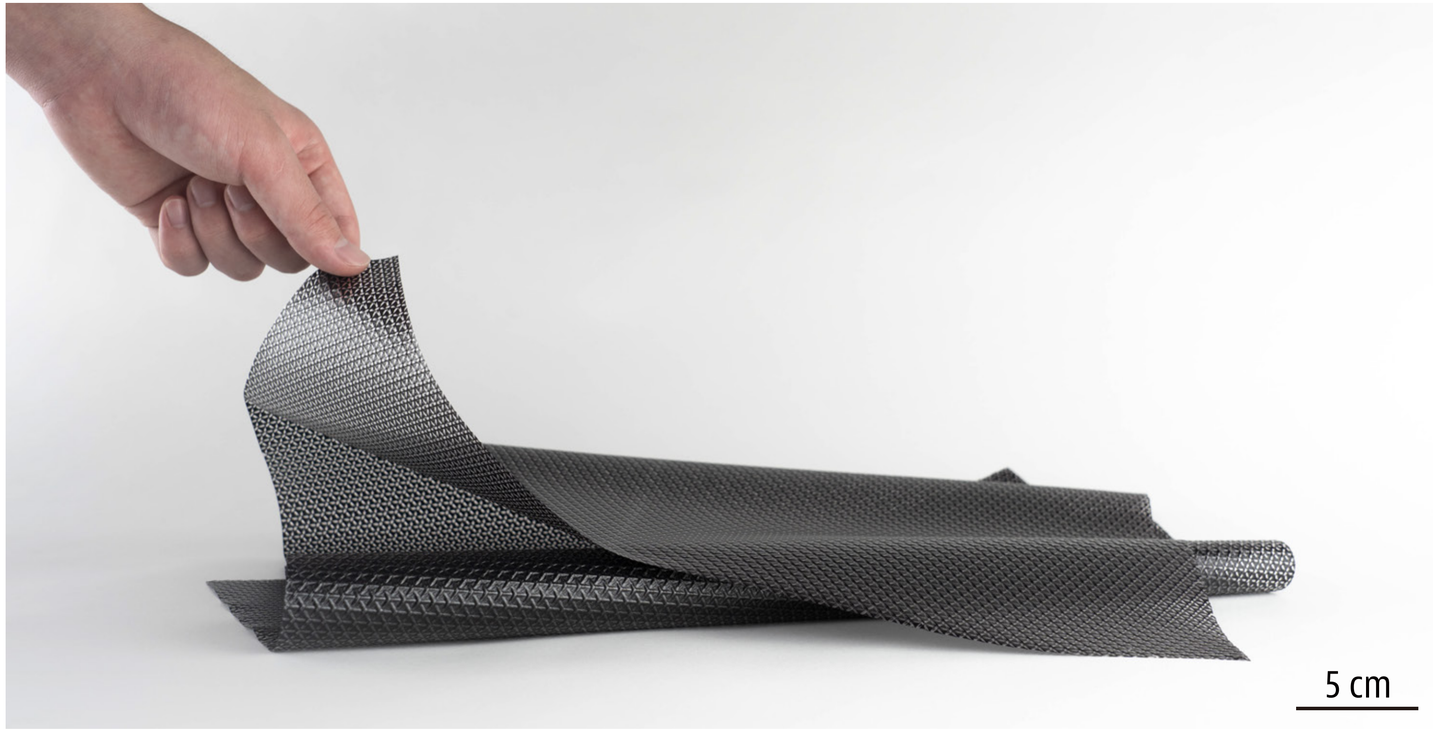
Resolution



l = 20 mm | l = 15 mm | l = 10 mm | l = 6.0 mm | l = 4.0 mm | l = 3.0 mm

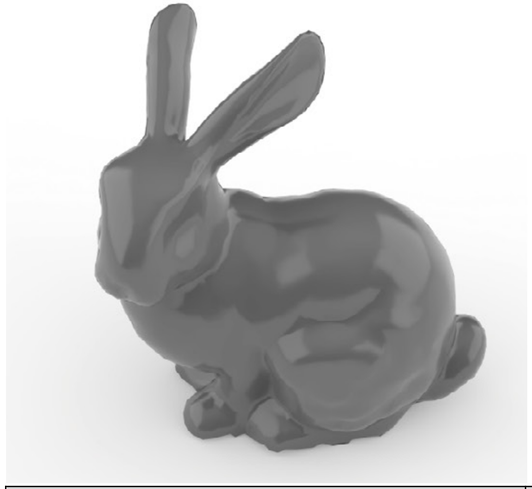
We defined the resolution by the edge length l of Ron Resch patterns.
Then, **the practical folding resolution was l = 3.0 mm**.

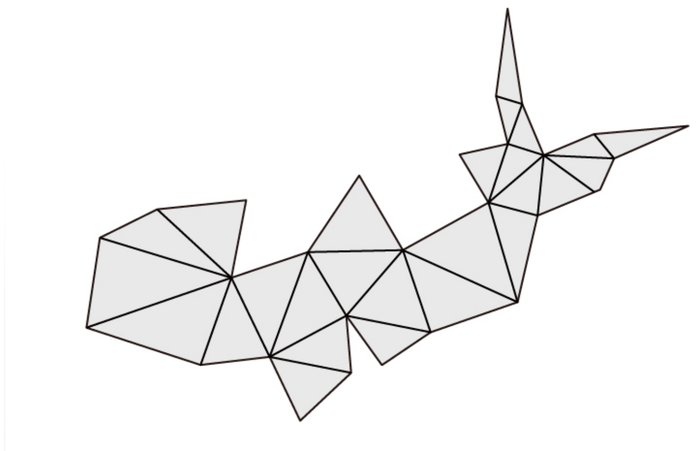
Resolution

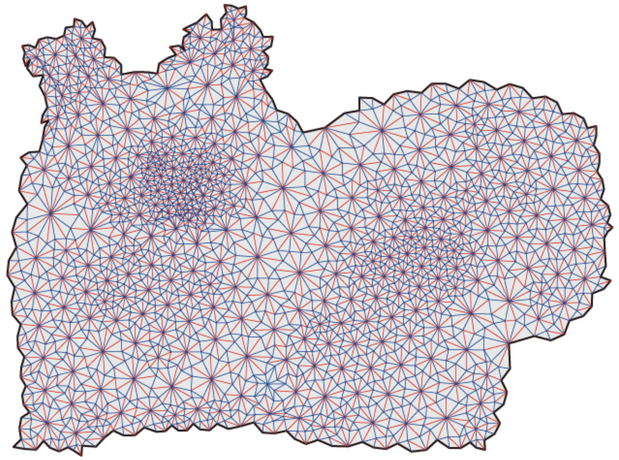


Our current setup allows for **at maximum an A2-sized sheet** with **at minimum 3.0 mm edges**. This means **88,008 self-foldable facets**, which is **>1000x more facets than prior 4D printing**.

Comparison: Complexity



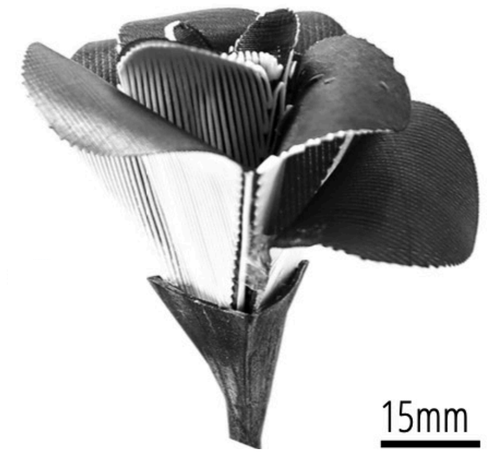


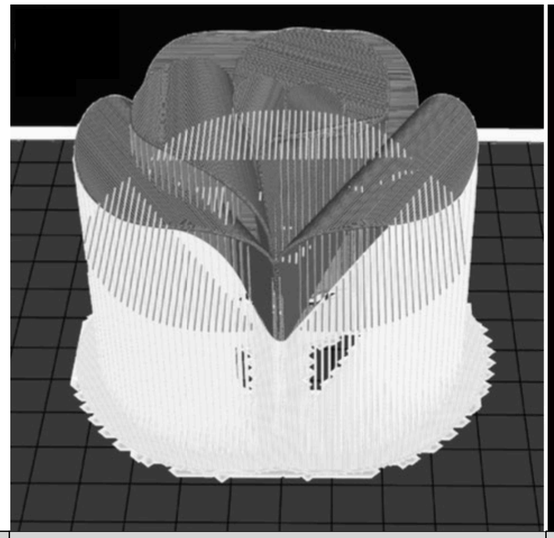


	Conventional 4D Printing [1]	**Inkjet 4D Print**
Hardware	FDM 3D printer	Inkjet UV Printer
Number of facets	26	4,299 (**> 150x than ever**)
Max number of facets	69	80,008 (**> 1200x than ever**)

[1] An et al., Thermorph, CHI2018.

Comparison: Support Materials and Speed





	FDM 3D printing [1]	Conventional 4D printing [1]	Inkjet 4D Print
Support material consumption	65 g	0 g	**0 g**
Printing time	8 h 47 m	1 h 12 m	0 h 26 m (**1/20 of 3D printing**)

[1] An et al., Thermorph, CHI2018.

Applications

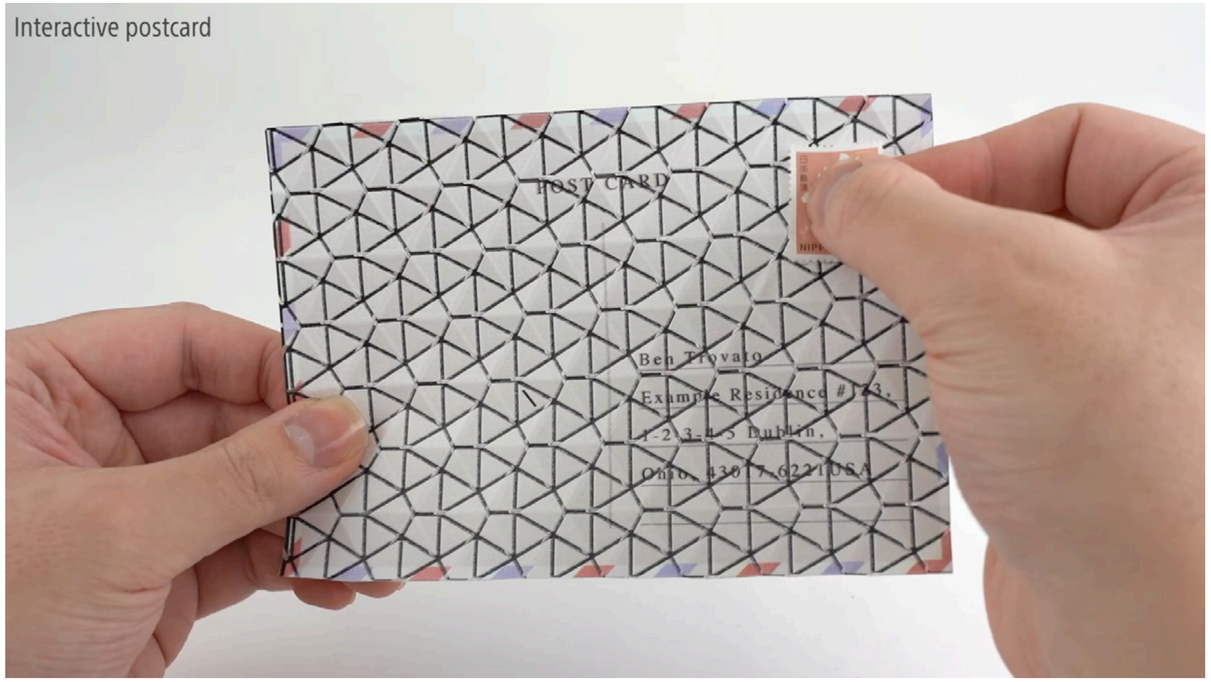
Fashion Items

Inkjet 4D Print achieves **complex shape** and **colors** at the same time.

A Ship in a Bottle

Inkjet 4D Print achieves **self-deployment even with a limited human access**

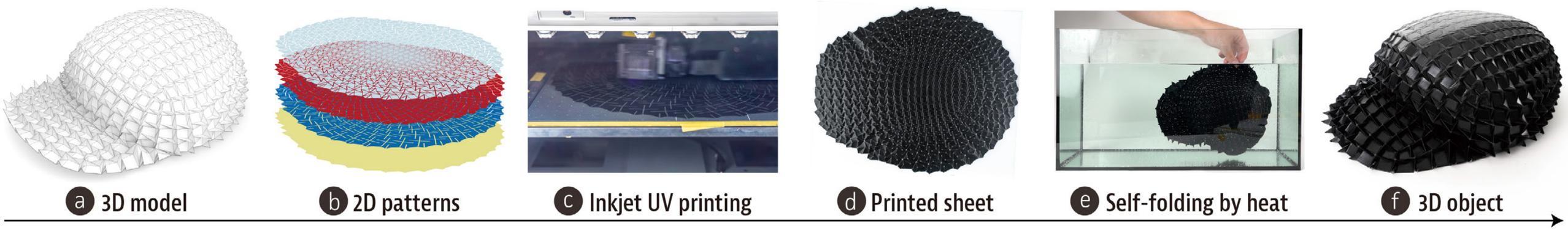
Interactive Postcard



Inkjet 4D Print achieves **interactive and encrypted message**.

Conclusions

Summary



Inkjet 4D Print enables:

1. Self-folding of complex origami patterns with **thousands of facets**;
2. Printing **20x faster than 3DP**, **without material waste**, in a **small volume**;
3. A single printing process achieves **both shape and texture**.

Media Coverage

- **東京大学（+他4者）プレスリリース**

折紙シートが自動で望みの立体に ―インクジェットプリンタでパターンを印刷、加熱により自動変形―

- **読売新聞 紙面およびオンライン**

折り紙はここまで進化、医学や宇宙開発など幅広い産業で応用期待…９万の面を持つ新技術

- **日経新聞 紙面およびオンライン**

温めると立体模型に変身、新しい折り紙シート　東京大学

- **日経産業新聞 紙面**

東大、熱で立体化するシート

- **GIZMODO**

UV印刷機で作る折り紙シートが、生活を大きく変えるかもしれない

- **ナショナルジオグラフィック日本版**

お湯をかけるとすぐ自動で望みの立体に、折紙シートの技術を開発

- **Yahoo!ニュース**
- **JSTサイエンスポータル**

「すぐ折れる、すごく折れる」折紙シート UVプリンターで印刷しお湯で立体に 東大など

- **CNN（2023/11/25放映）**

Tech for Good: The science and high-tech promise of origami

- **fabcross**

折紙シートが自動で立体に――東大など、数万個の面を持つ多面体を自動的に折る技術を開発

- **Bouncy**

温めると自動で立体化！ 日本発の折り紙シート技術「Inkjet 4D Print」

- **WIRED**

平面のシートが自律的に立体物に！“折り紙”を応用した日本発の技術「インクジェット4Dプリント」の潜在力

- **WIRED**

拡張される東京2020大会エンブレム：数理が生成するアート「つながるかたち展」の舞台裏

- **テレビ東京WBS「トレたま」（2023/09/05放映）**

シートが自動で立体に

- **子供の科学**

折紙が自動的に複雑な立体に変身しちゃう

- **日本テレビ「博士は今日も嫉妬する」（2023/10/29放映）**

自動で立体になる折り紙

- **フジテレビ「もしもで考える…なるほど！なっとく塾」（2023/09/16放映）**

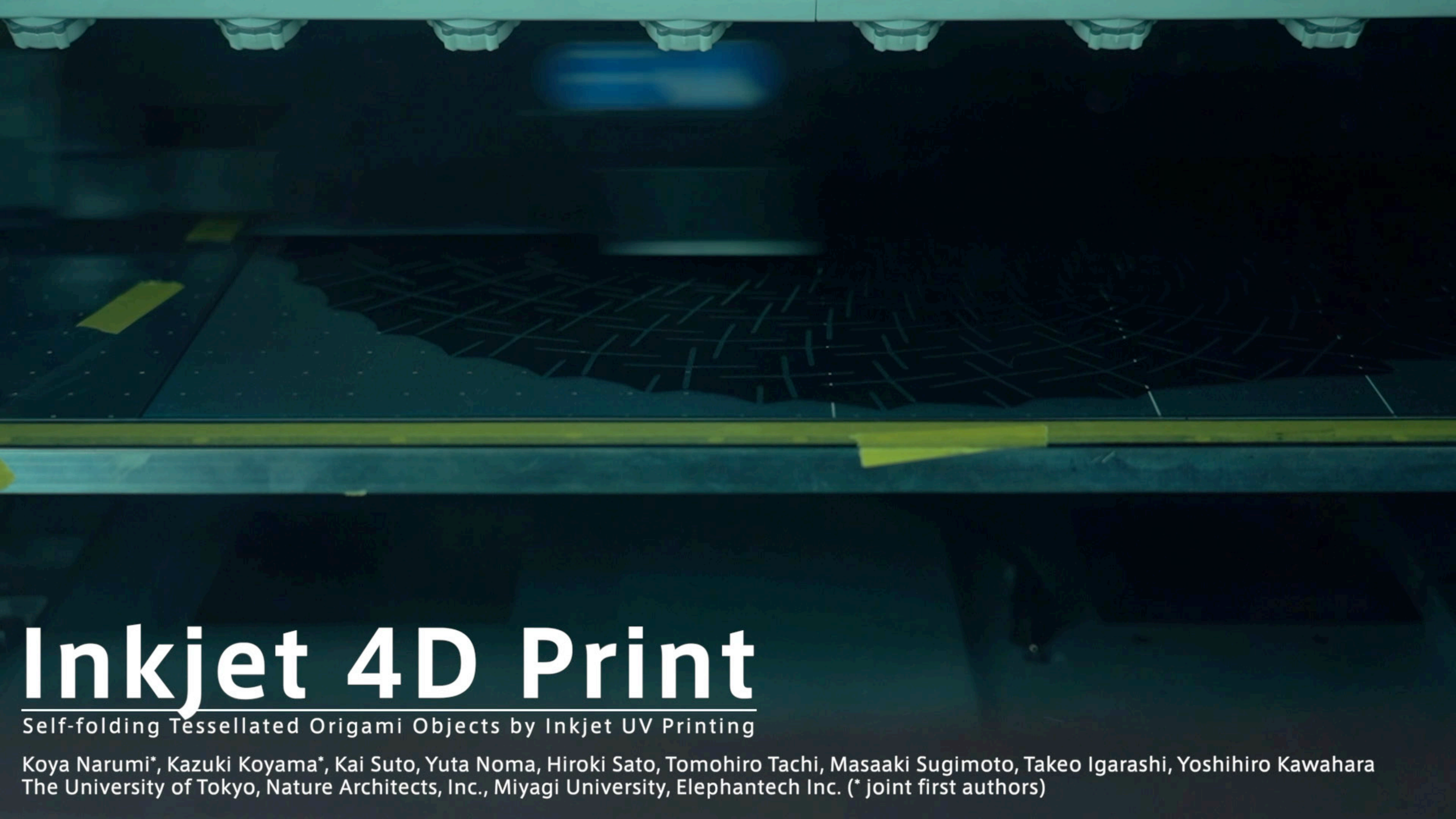
もしも折り紙を活用したら？

- **Dragon Ball Official**

ホイポイカプセルって実現できるの？「持ち運べる乗り物」を開発する工学の専門家に聞いてみた

下線部は記事へのリンク

My Project in a Taxi



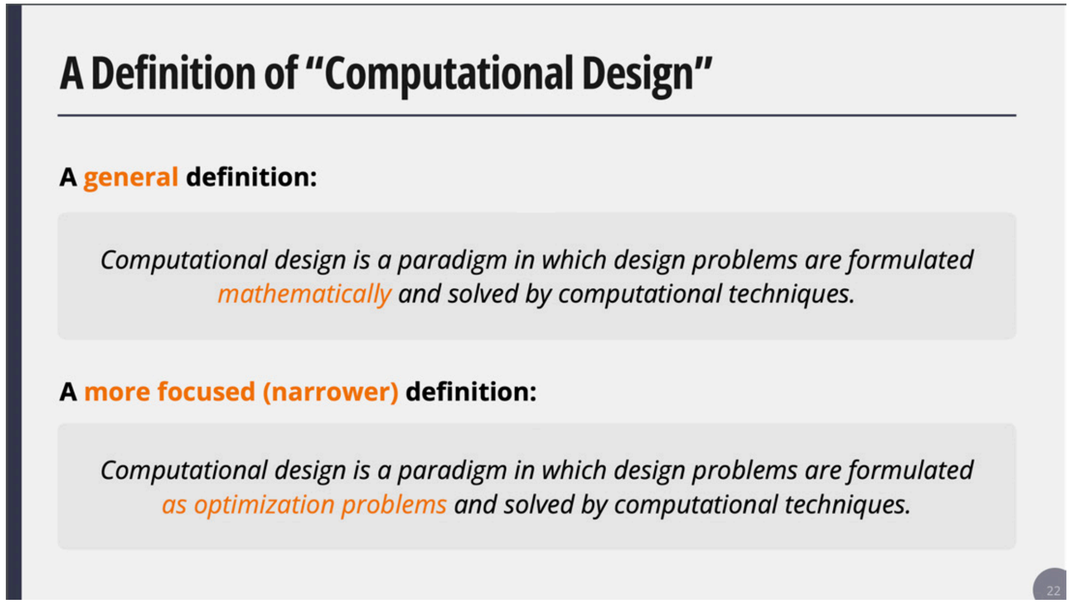
Inkjet 4D Print

Self-folding Tessellated Origami Objects by Inkjet UV Printing

Koya Narumi*, Kazuki Koyama*, Kai Suto, Yuta Noma, Hiroki Sato, Tomohiro Tachi, Masaaki Sugimoto, Takeo Igarashi, Yoshihiro Kawahara
The University of Tokyo, Nature Architects, Inc., Miyagi University, Elephantech Inc. (* joint first authors)

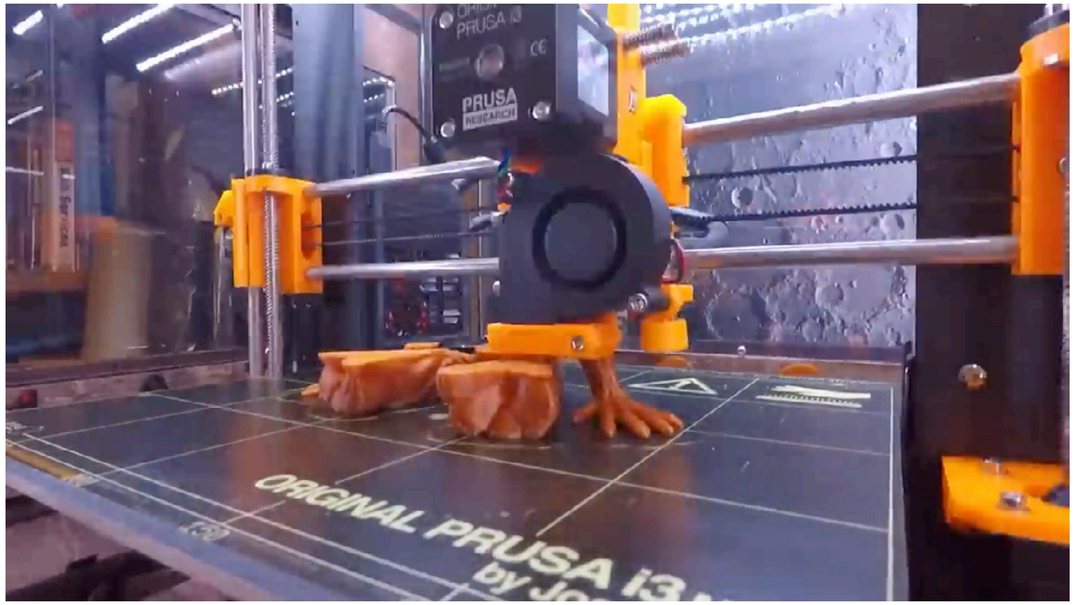
Conclusions

What is Computational Fabrication?



Computational Design [1]

+



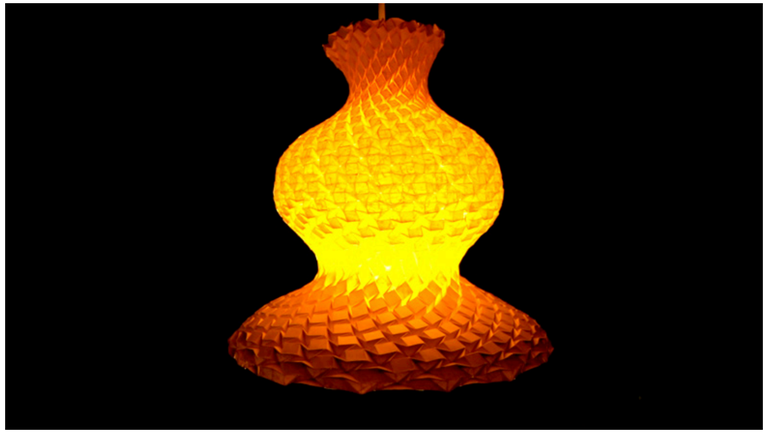
Digital Fabrication

Computational Fabrication refers to fabrication of "computationally designed objects" **under the constraints of real tools, materials, and structures**.

[1] Yuki Koyama, Introduction to Computational Design, CHI 2021 Courses.

Origami-inspired Computational Fabrication

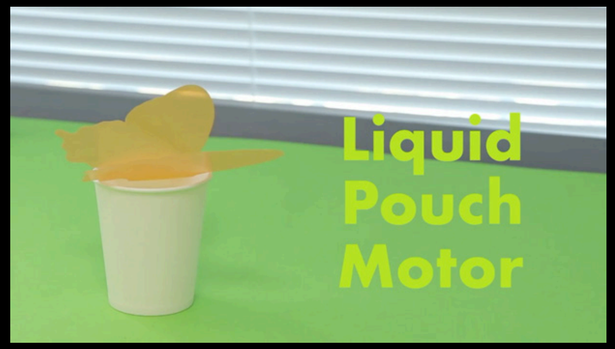
Pop-up Print
ACM UIST 2020

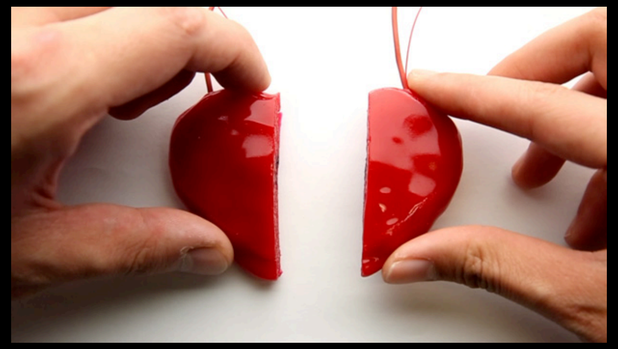


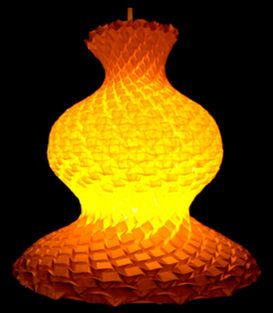
Crane
ACM TOCHI (CHI) 2023

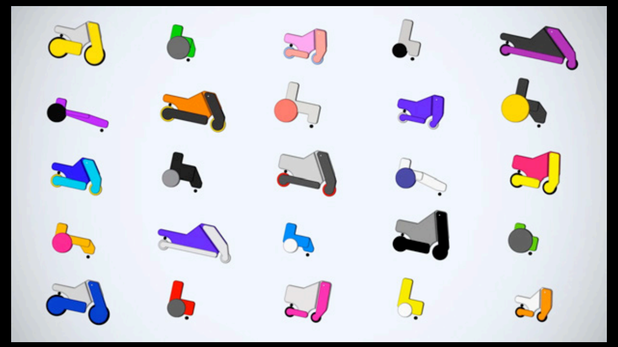
Inkjet 4D Print
ACM TOG (SIGGRAPH) 2023

Origami-inspired Computational Origami Fabrication | Koya Narumi





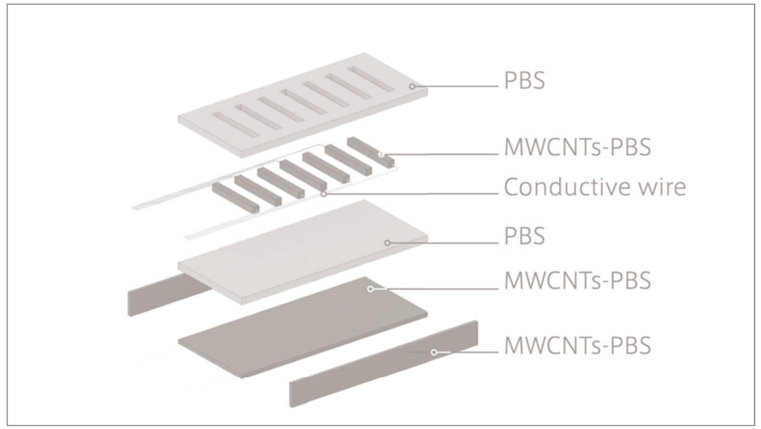




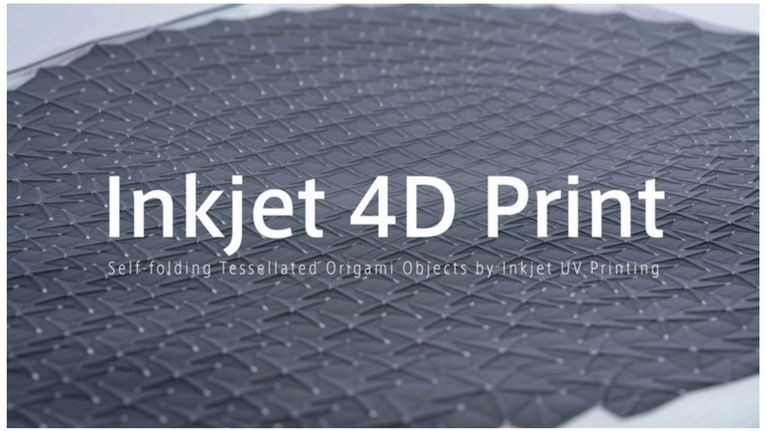
CONCLUSIONS

Three presentation methods

Week 3: **Slides**



Week5: **Figures**



Week6: **Videos**

Today's topics

Video-shooting environment

I like to take videos **in the same environment as photos**.

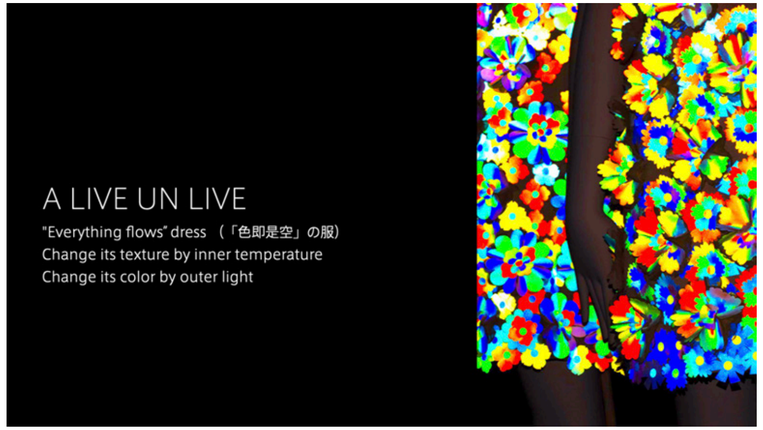
Video examples from my videos

Six video tips from my past videos.

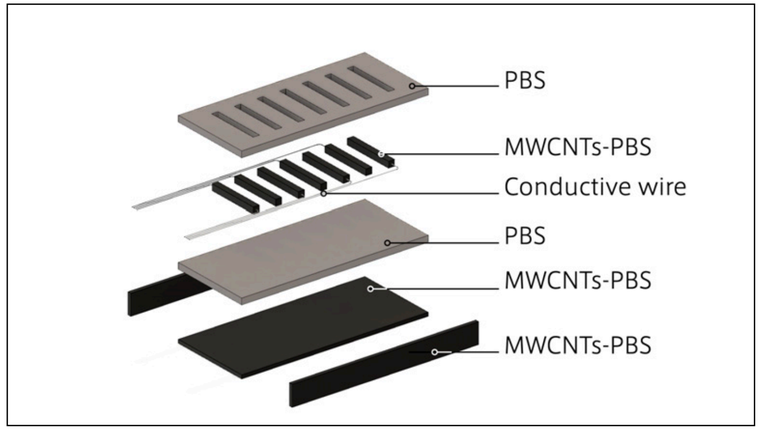
Other video examples

Let's check **other great videos**.

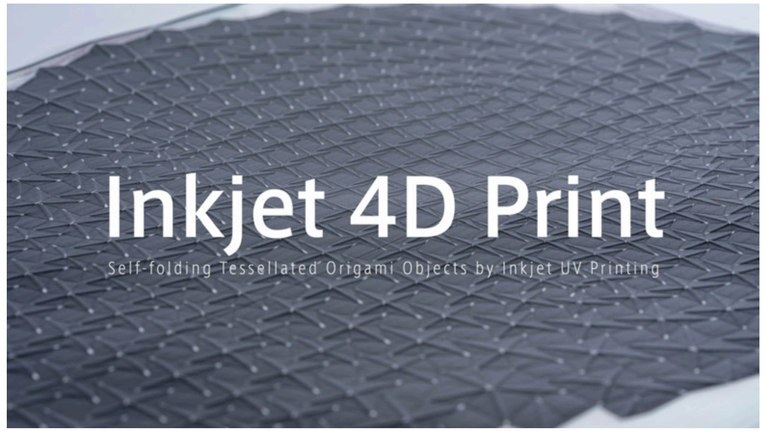
Three presentation methods



Week 3: **Slides**



Week5: **Figures**



Week6: **Videos**

“Interesting and unpublished” is equivalent to “non-existent.”

– George Whitesides

Let’s publish your achievement **effectively and beautifully.**

Next Week

Invited Talk 1: Conducting AI Research on High-Performance Computing (HPC) Systems

Yoshiaki Bando (AIST)