The main body of this slide is the first 150 pages.
The rest 200 pages are my design examples.

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

Slides

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

Disclaimer

Slide design is totally up to you

You learn some design methods, but don't need to stick to them.

Quality-vs-time tradeoff

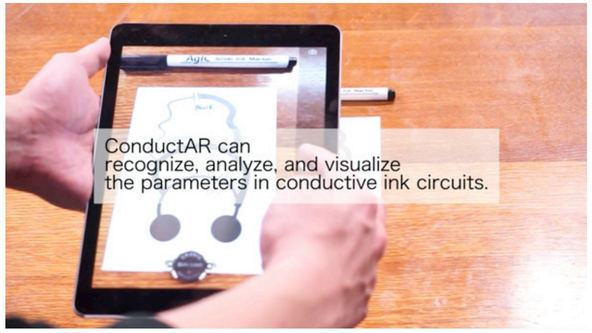
Any type of good presentation requires **long time** to prepare.
Consider how much time you can spend for preparation.

Presentation is as important as research

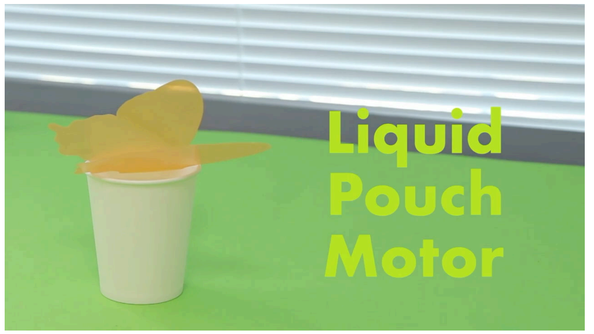
If no one knows, good research is useless.

Presentation lasts even after you leave academia.

Circuit Eraser
ACM CHI EA 2015, Kickstarter



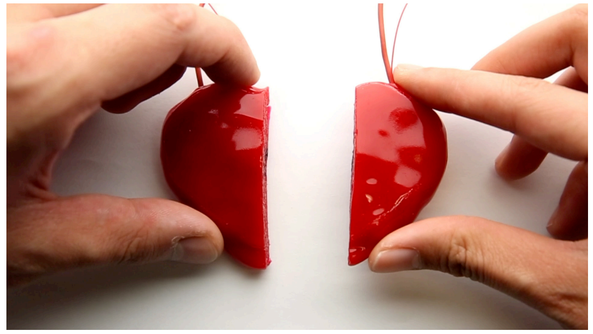
ConductAR
ACM UbiComp 2016



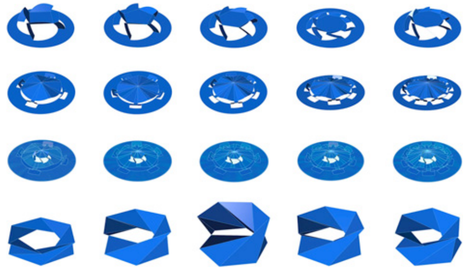
Liquid Pouch motors
IEEE ICRA 2017, IEEE RA-L 2020

Papilion
Ars Electronica 2017

A LIVE UN LIVE
六本木クロッシング 2018



Self-healing UI
ACM UIST 2019

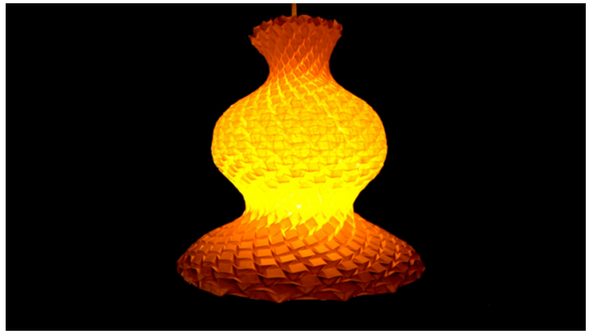


Kirigami Haptic Swatches
ACM CHI 2020

Pop-up Print
ACM UIST 2020

poimo
ACM UIST 2020

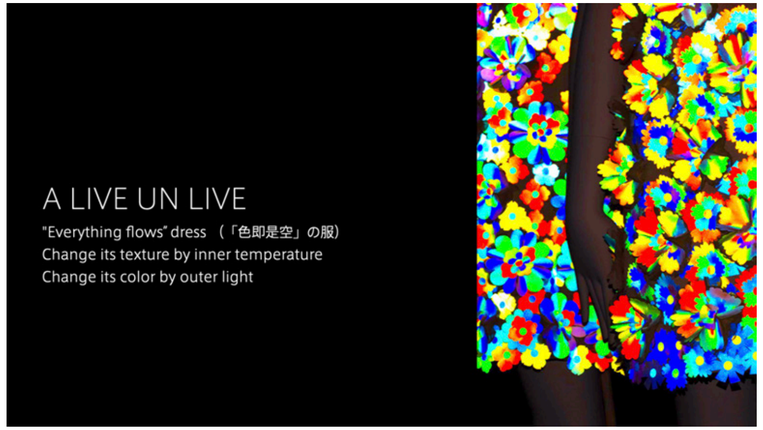
Flower Jelly Printer
ACM CHI 2021



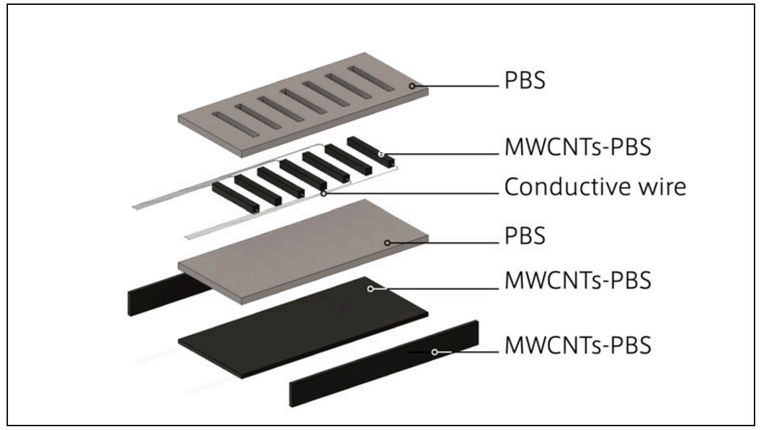
Crane
ACM TOCHI (CHI) 2023

Inkjet 4D Print
ACM TOG (SIGGRAPH) 2023

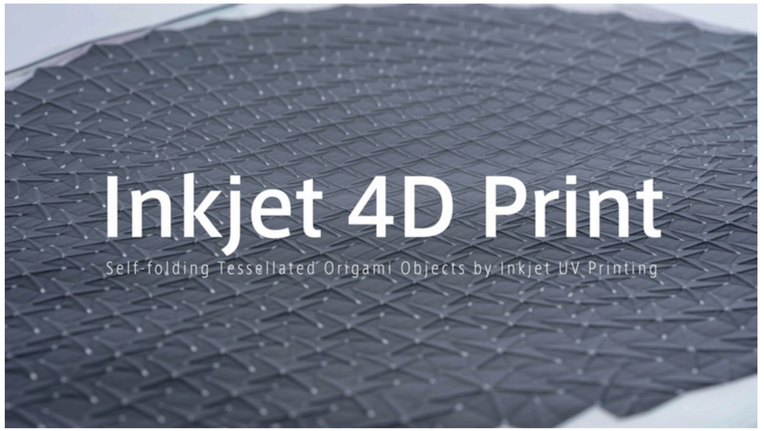
Lets study three presentation methods



Week 3: **Slides**

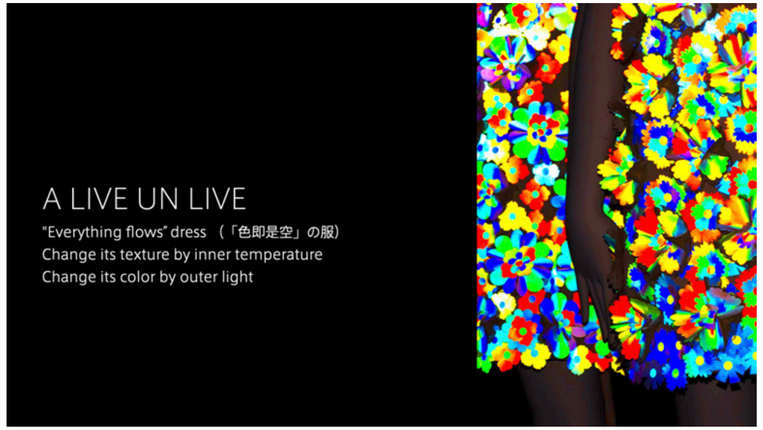


Week5: **Figures**

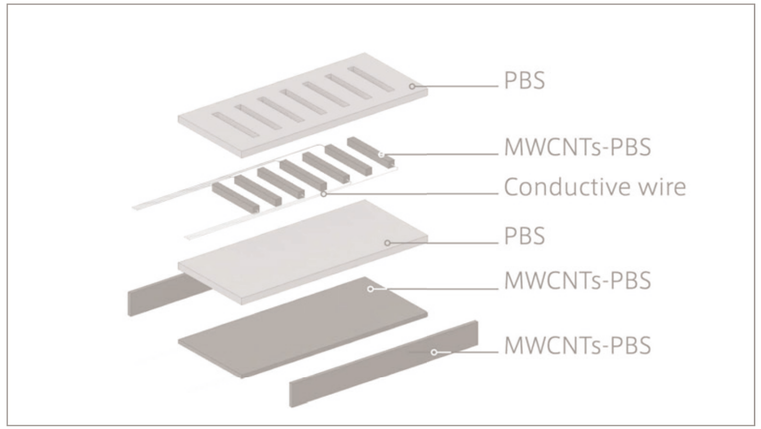


Week6: **Videos**

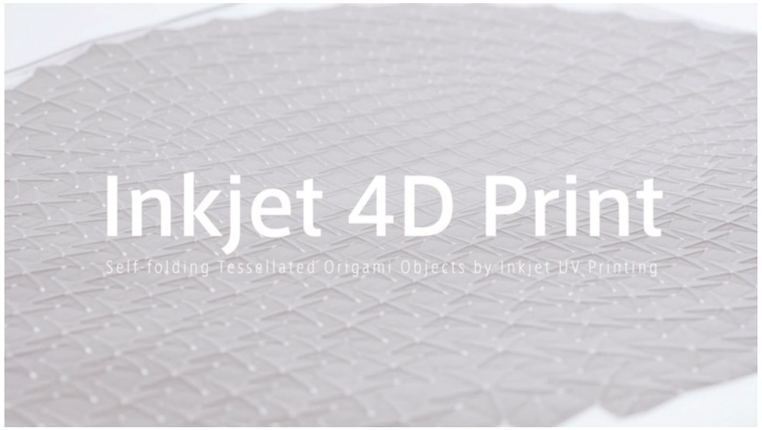
Lets study three presentation methods



Week 3: **Slides**



Week5: **Figures**



Week6: **Videos**

Week 1 : Slide

Basic

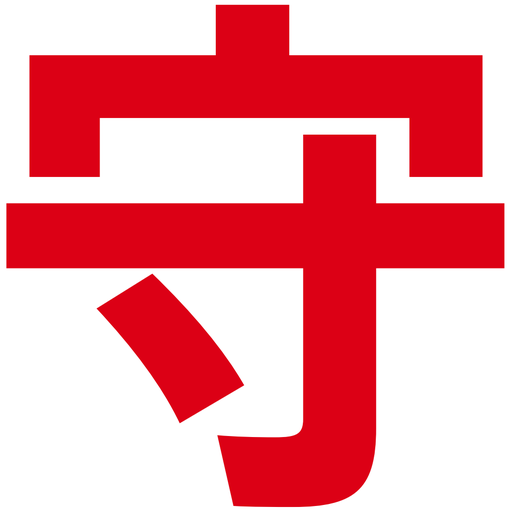
守

Advanced

展

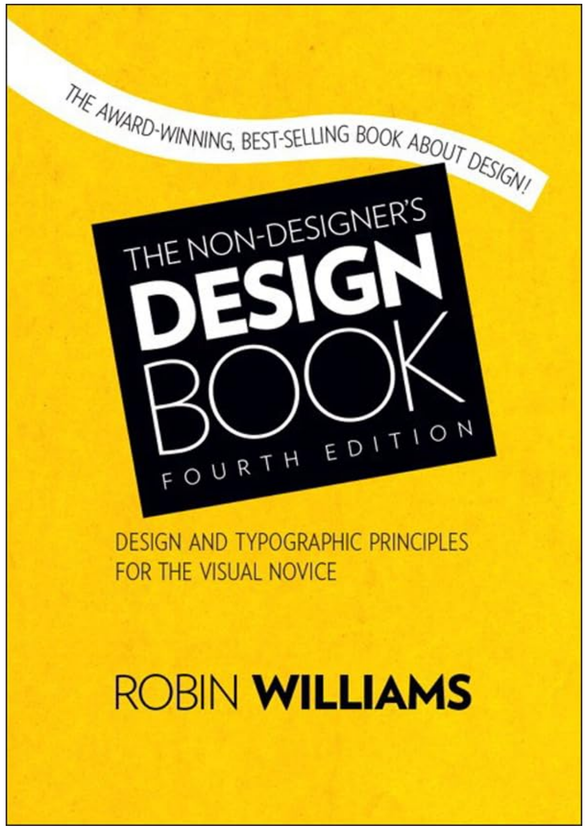
Week 1: Slide

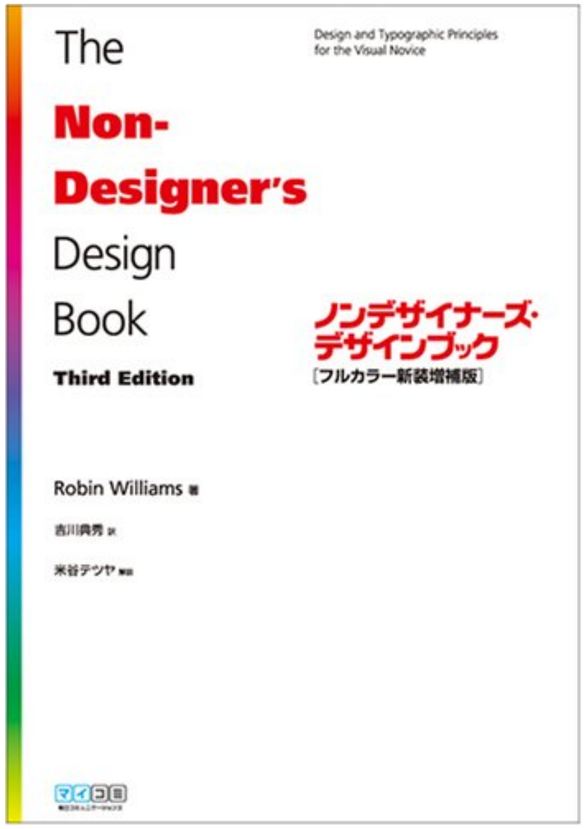
Basic



Advanced

Four Design Principles as Basics





"The Non-Designer's Design Book," English edition & Japanese edition

Four Design Principles as **Basics**

Proximity

Related contents must be **close**. **Unrelated contents** must be **far.**

Alignment

Invisible lines should be as **clear and few** as possible.

Repetition

Repeated concepts improves **consistency.**

Contrast

Meaningful contrasts are **strong rather than subtle.**

Concepts are cited from "The Non-Designer's Design Book"

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Proximity: Name Card

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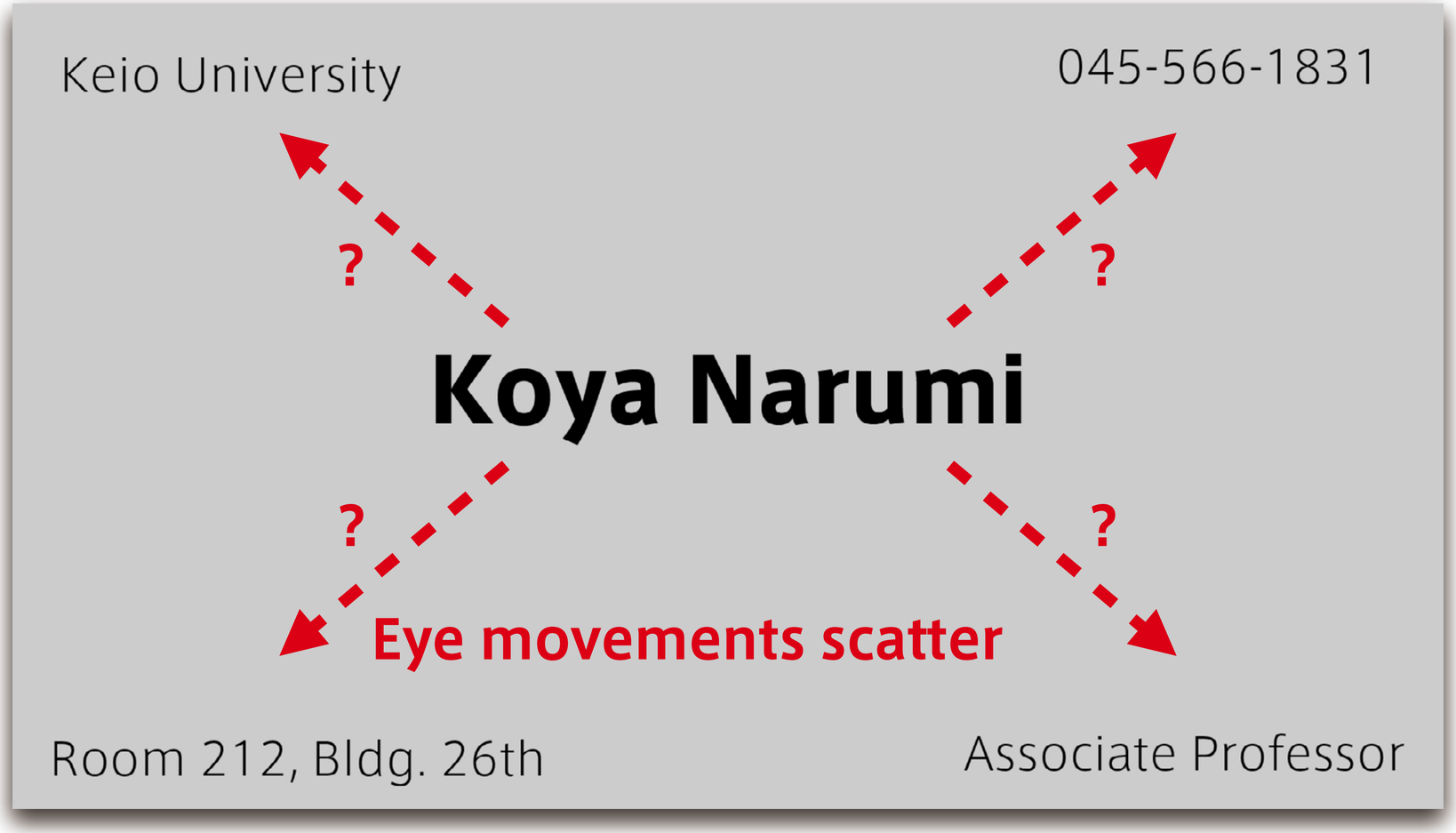

Concepts are cited from "The Non-Designer's Design Book"

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Koya Narumi
Associate Professor

Room 212, Bldg. 26th
Keio University
045-566-1831

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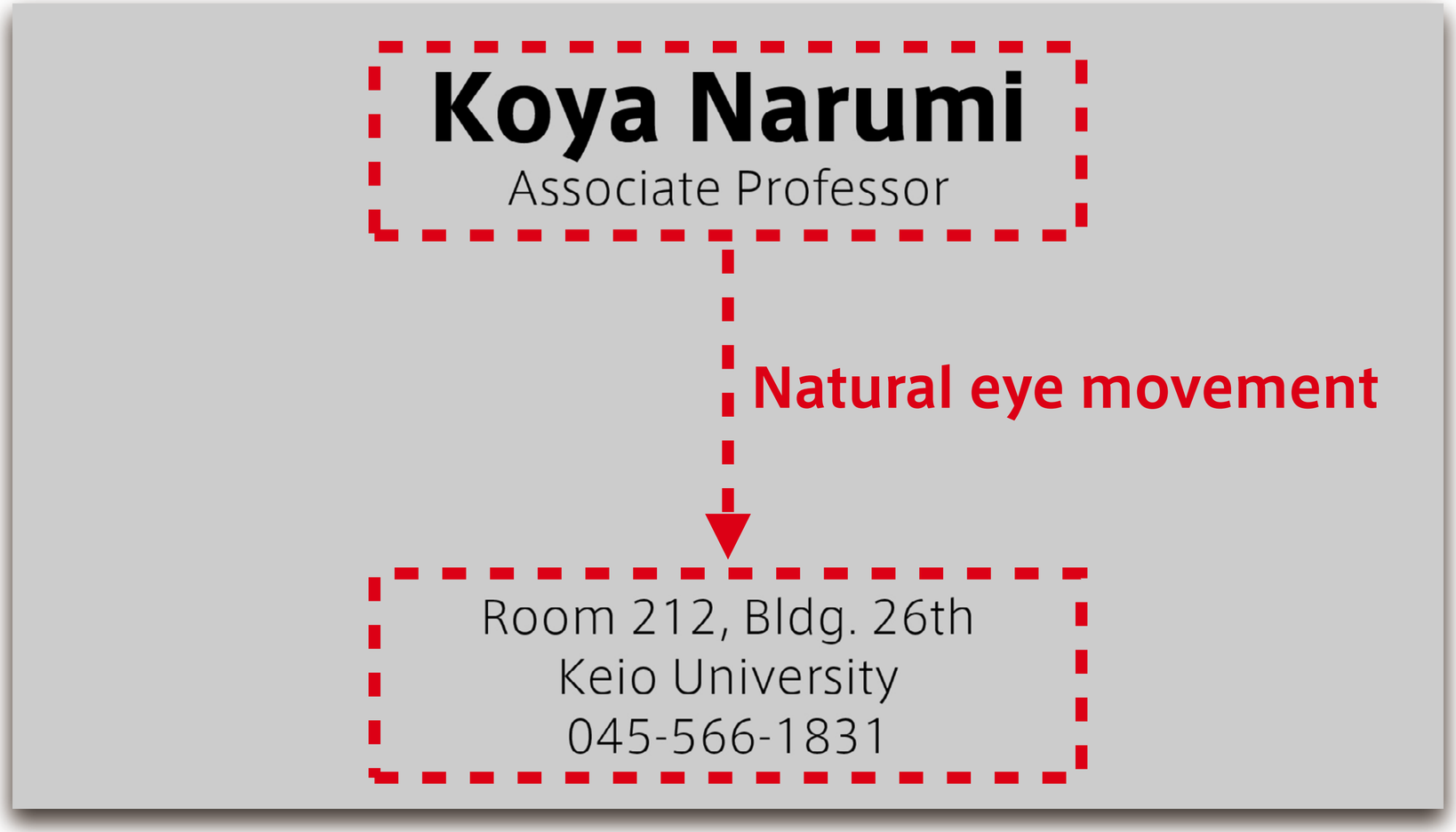


Concepts are cited from "The Non-Designer's Design Book"

Proximity: Name Card

OK

Better

Related contents must be **close.**

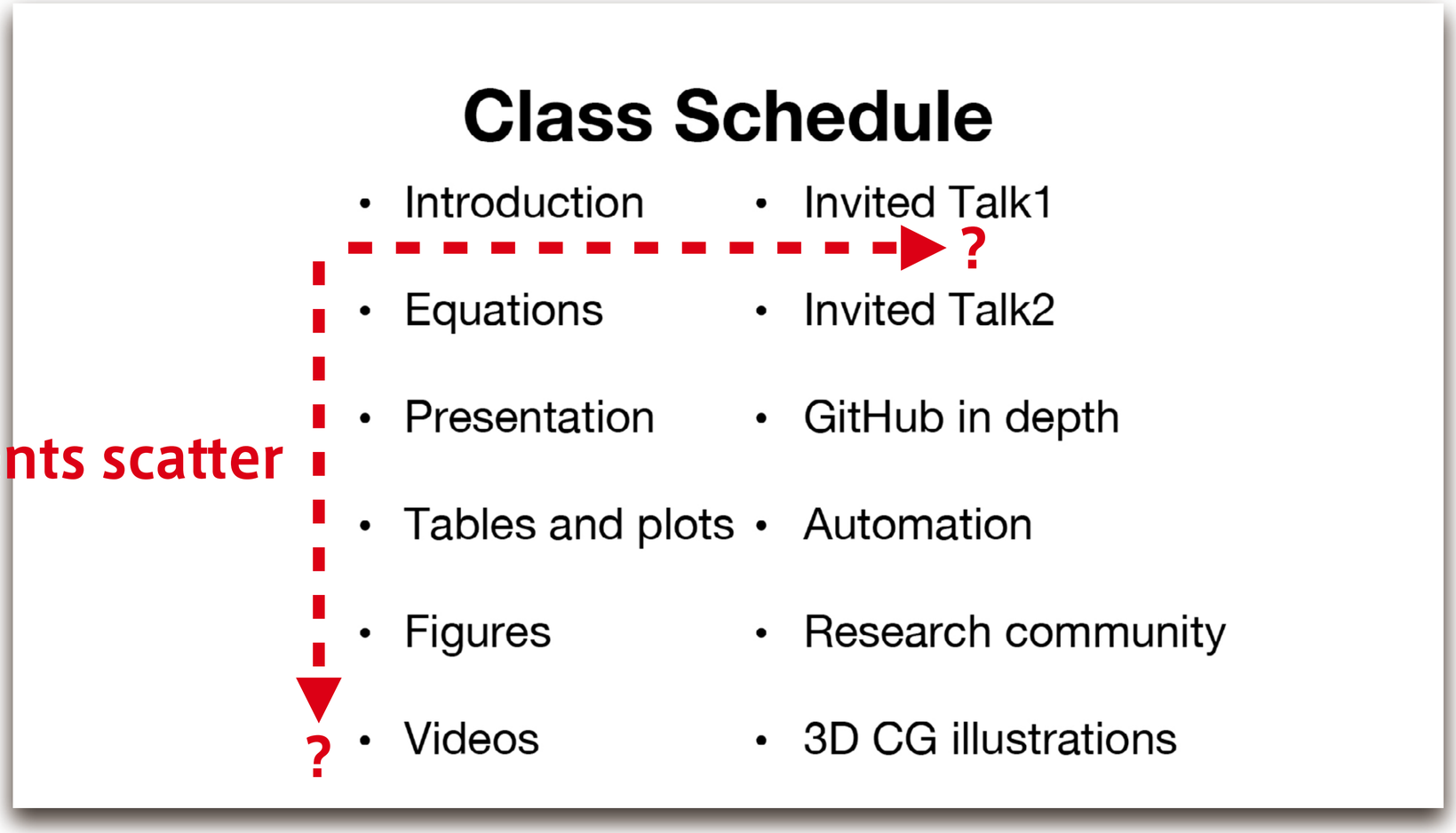
Concepts are cited from "The Non-Designer's Design Book"

Proximity: Itemization

Class Schedule

- Introduction
- Equations
- Presentation
- Tables and plots
- Figures
- Videos
- Invited Talk1
- Invited Talk2
- GitHub in depth
- Automation
- Research community
- 3D CG illustrations

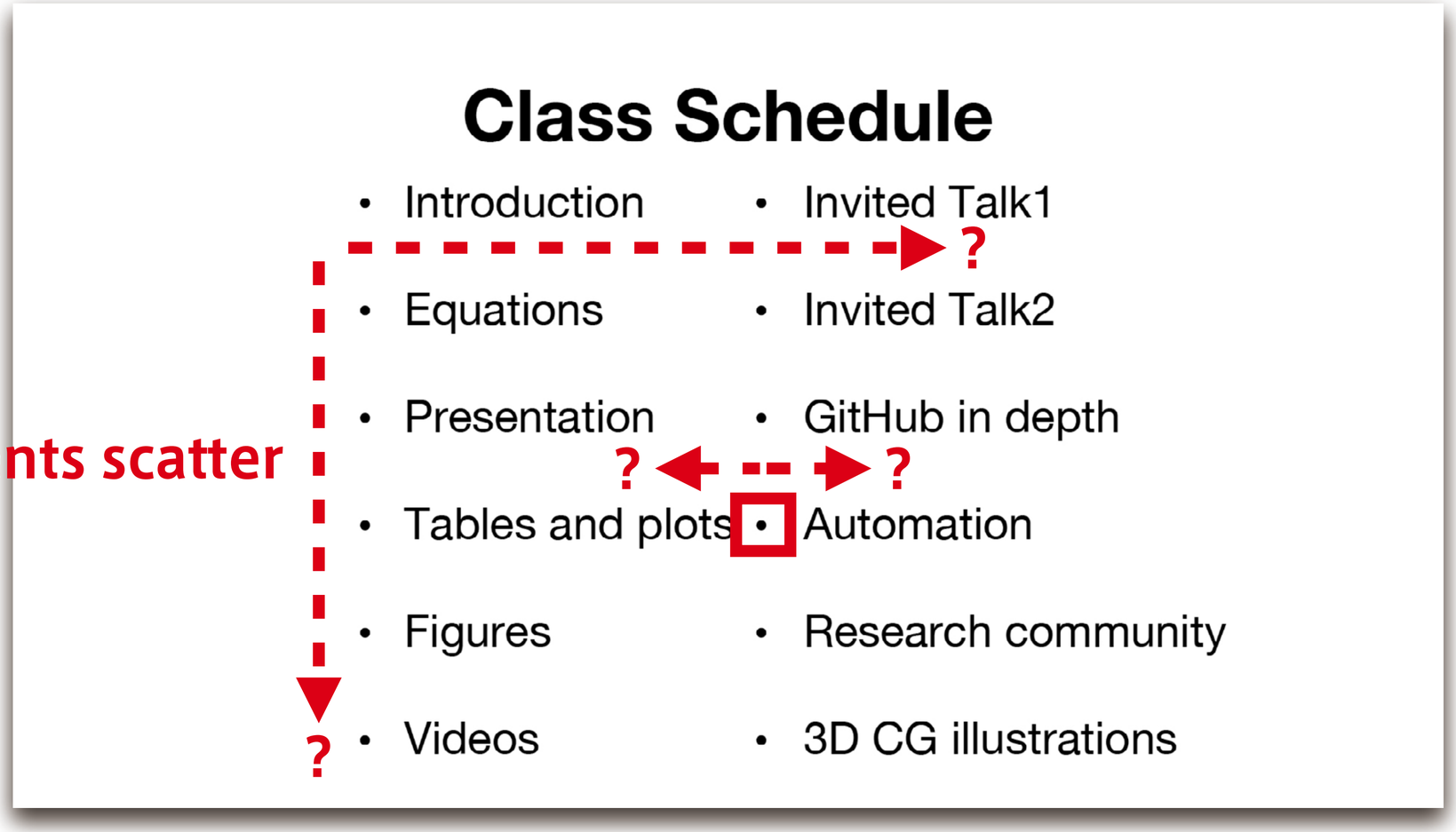
Proximity: Itemization



Eye movements scatter

Proximity: Itemization

Eye movements scatter



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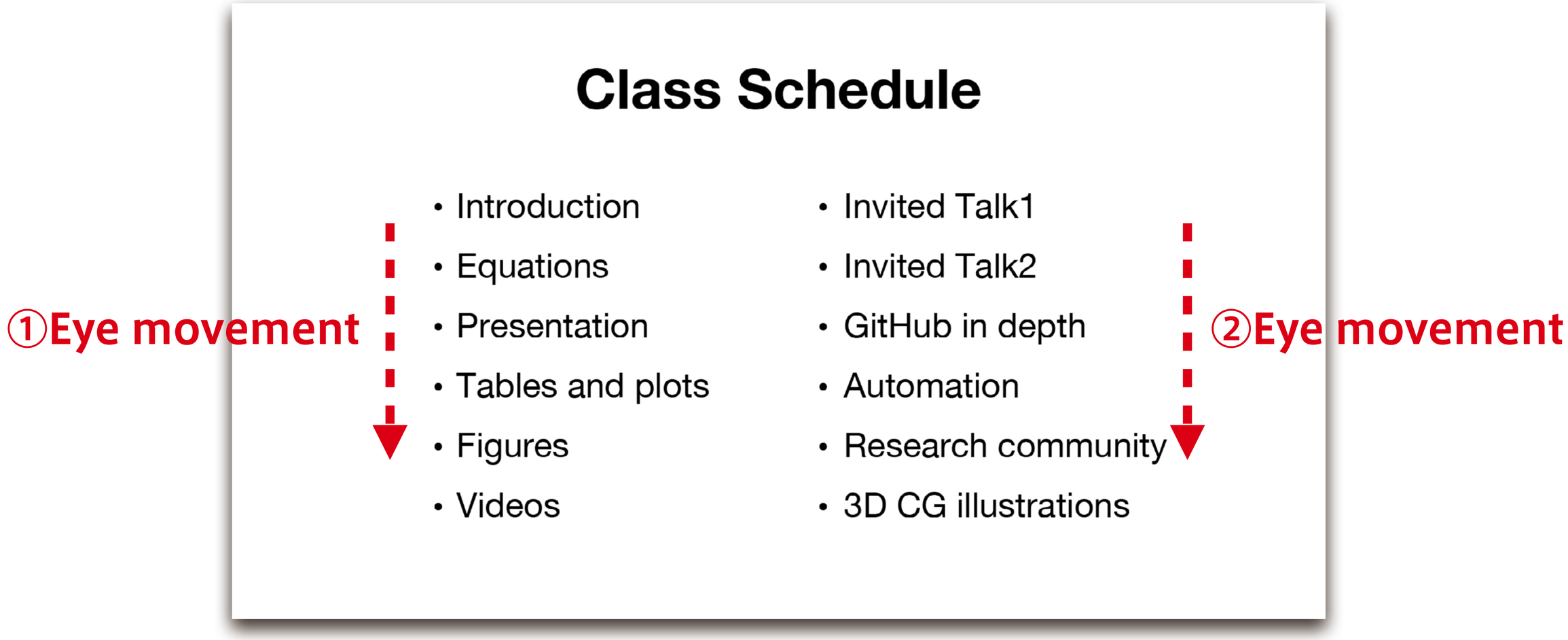

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Better

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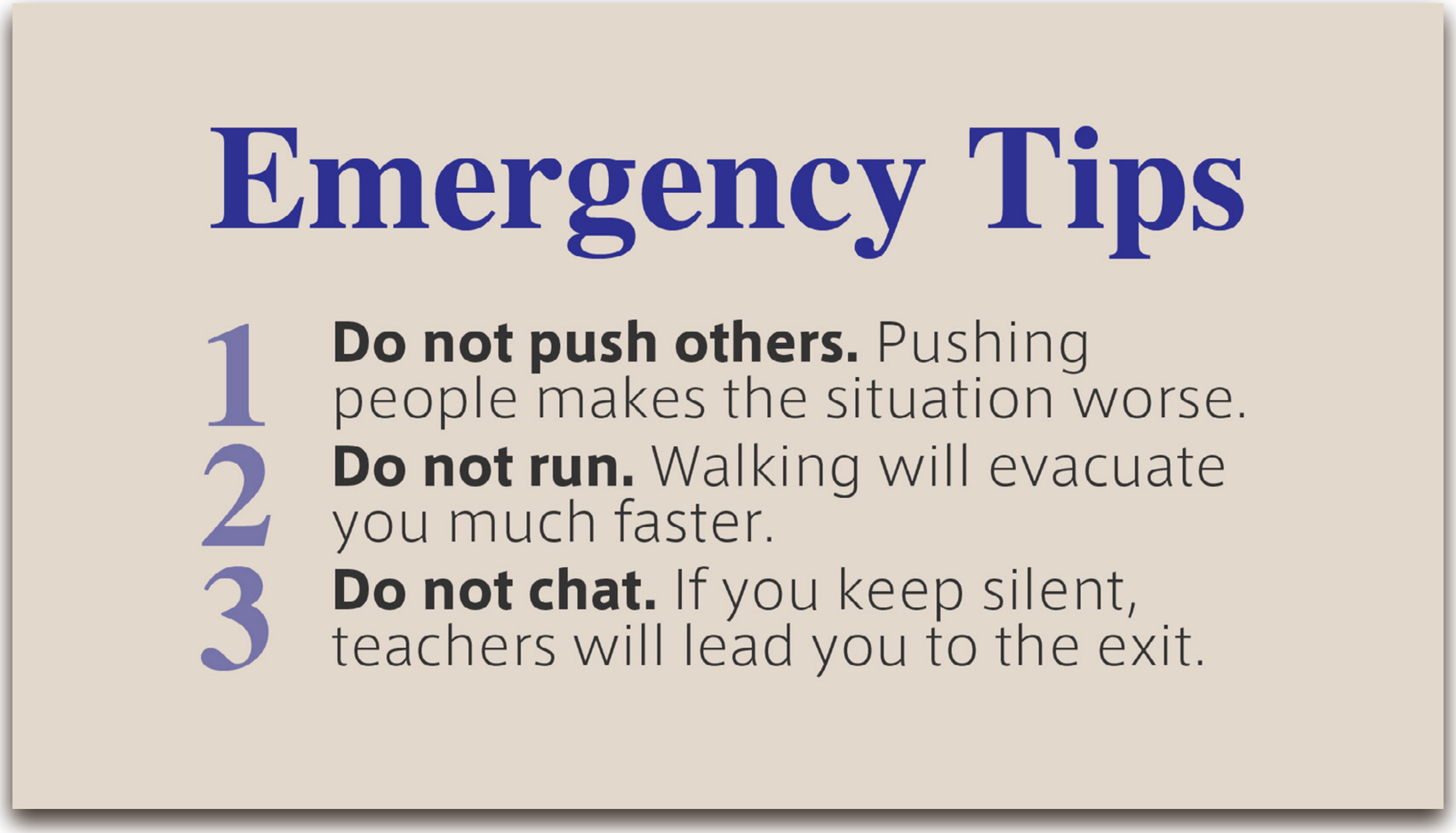
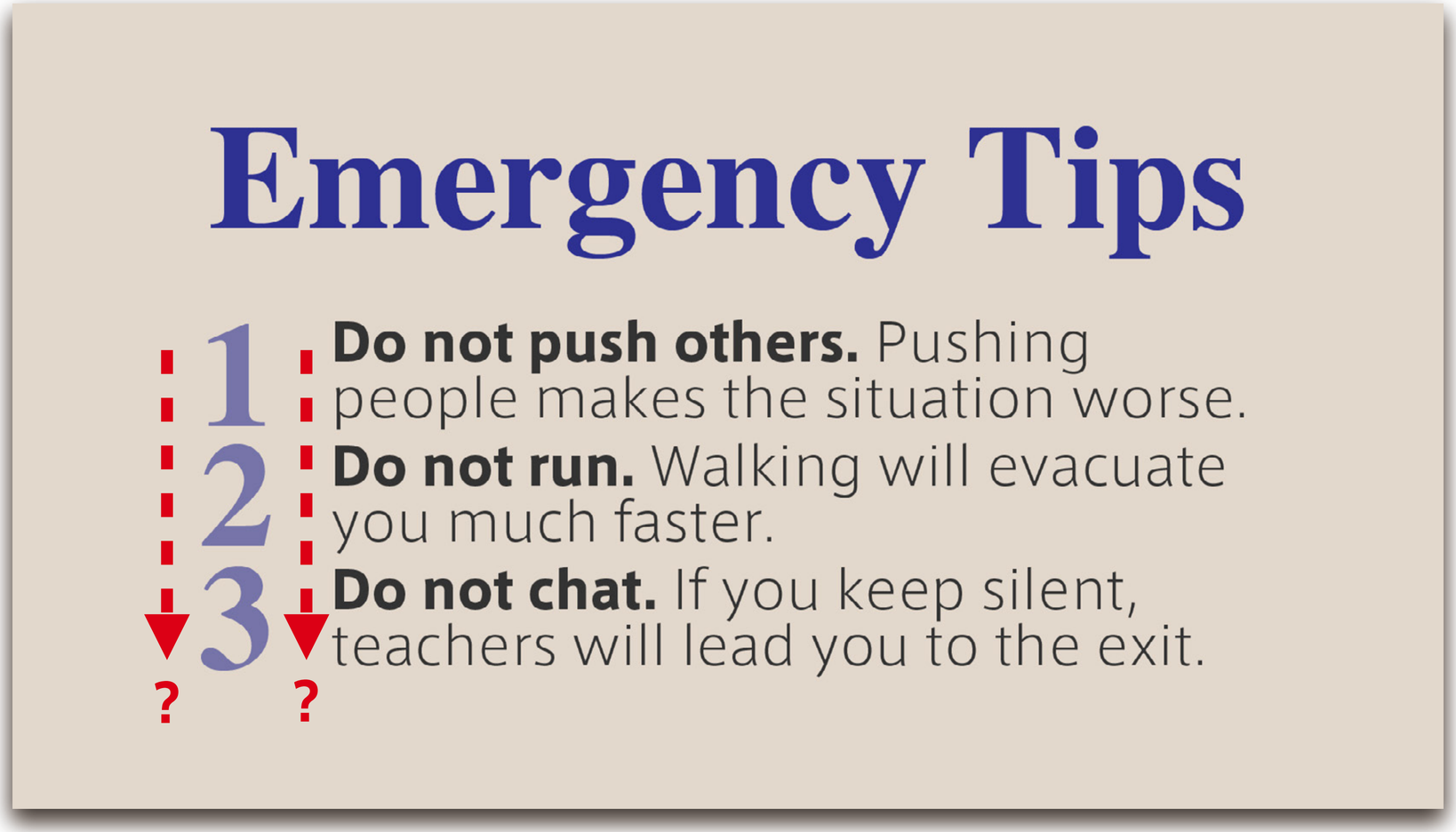
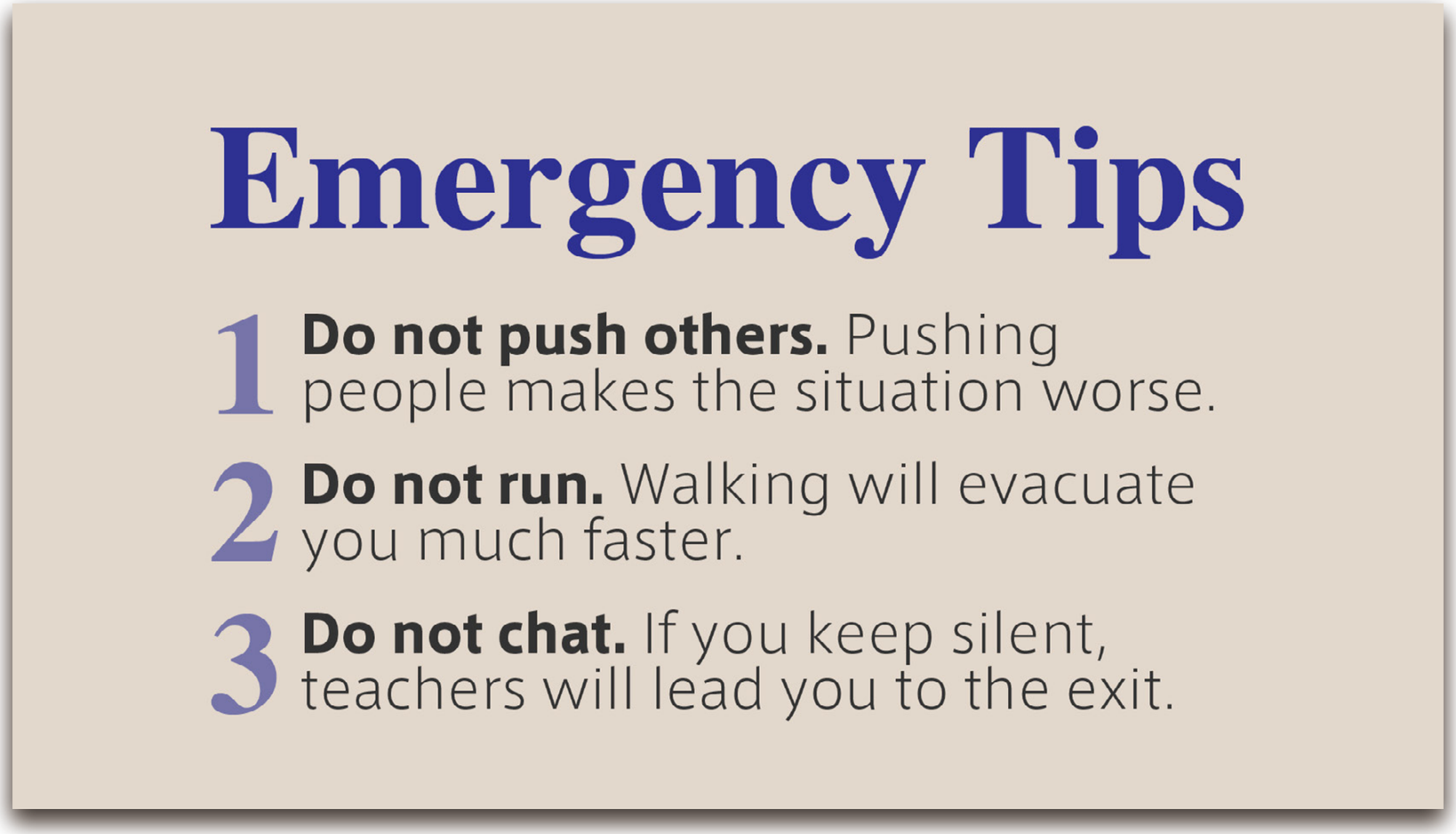
Proximity: Numbers



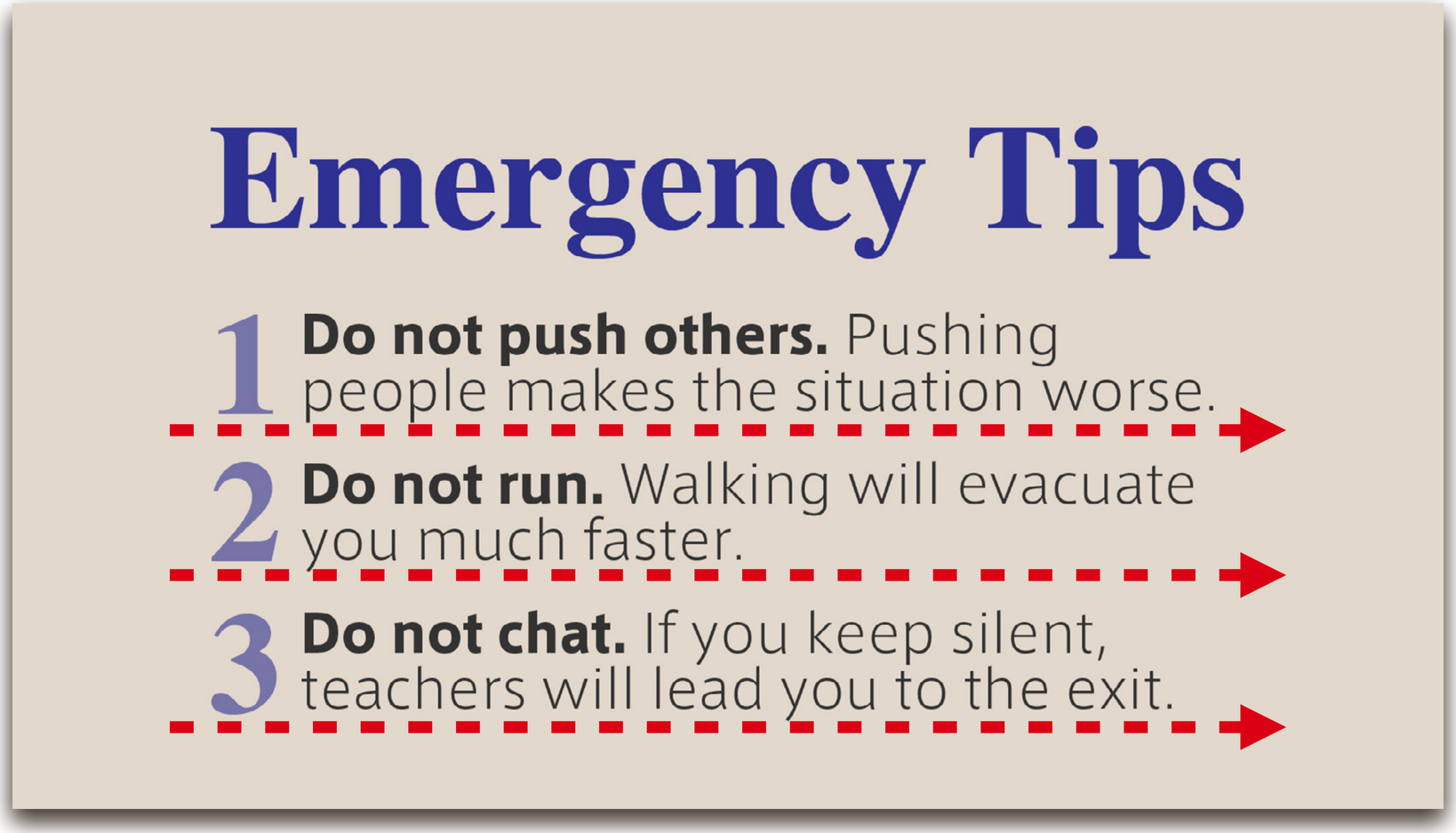
Proximity: Numbers



Proximity: Numbers



Proximity: Numbers



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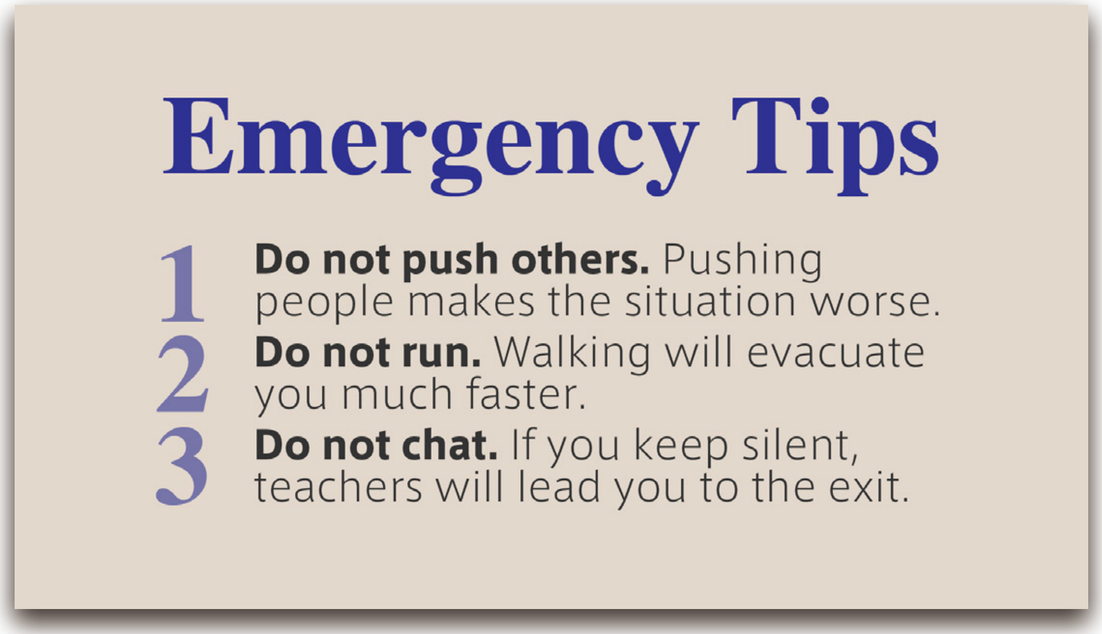
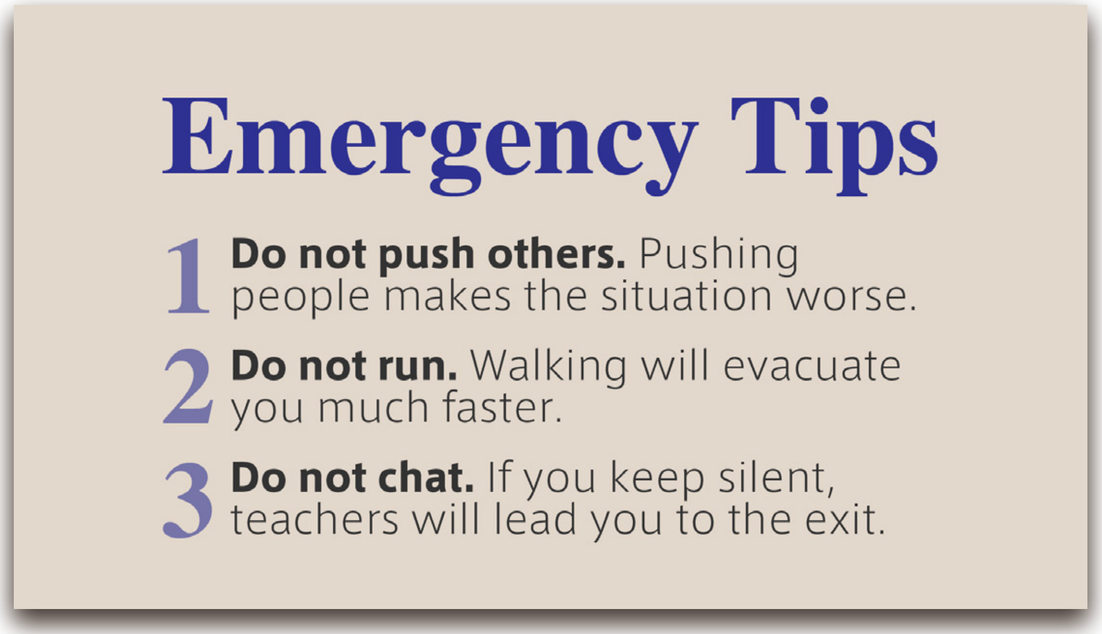


OK



Better

Related contents must be **close.**
Unrelated contents must be **far.**

Concepts are cited from "The Non-Designer's Design Book"

Proximity: Title Slide

Proximity: Title Slide

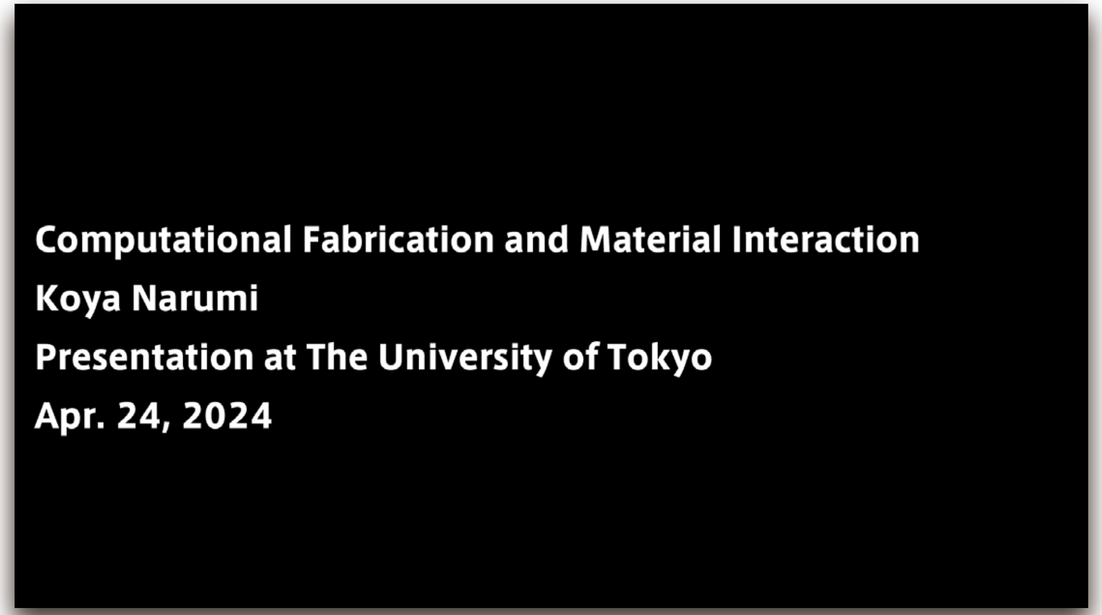
Which one is important?

Proximity: Title Slide

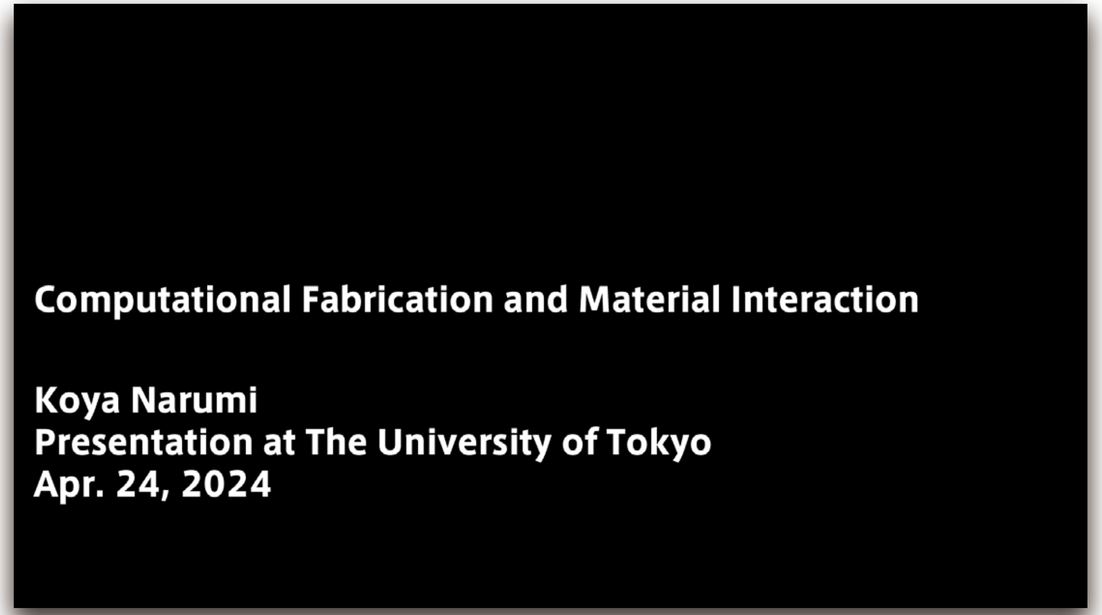
Proximity: Title Slide

Concepts are cited from "The Non-Designer's Design Book"

Proximity: Title Slide



OK



Better

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Four Design Principles as **Basics**

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Concepts are cited from "The Non-Designer's Design Book"

ALIGNMENT

Invisible lines should be as clear and few as possible

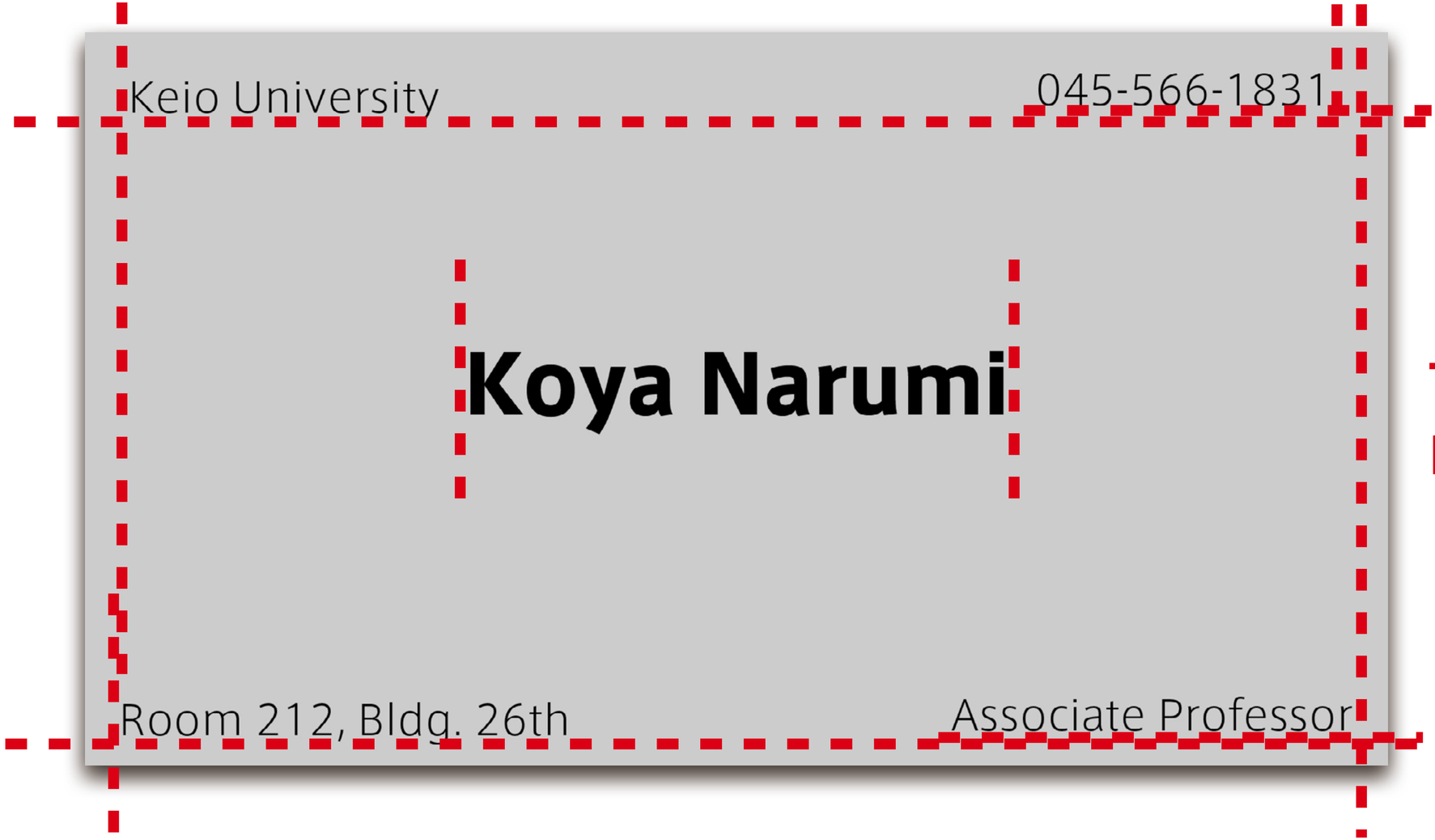
In short,

All the objects in a slide are placed with reasons.

Concepts are cited from “The Non-Designer’s Design Book”

Alignment: Name Card

Alignment: Name Card



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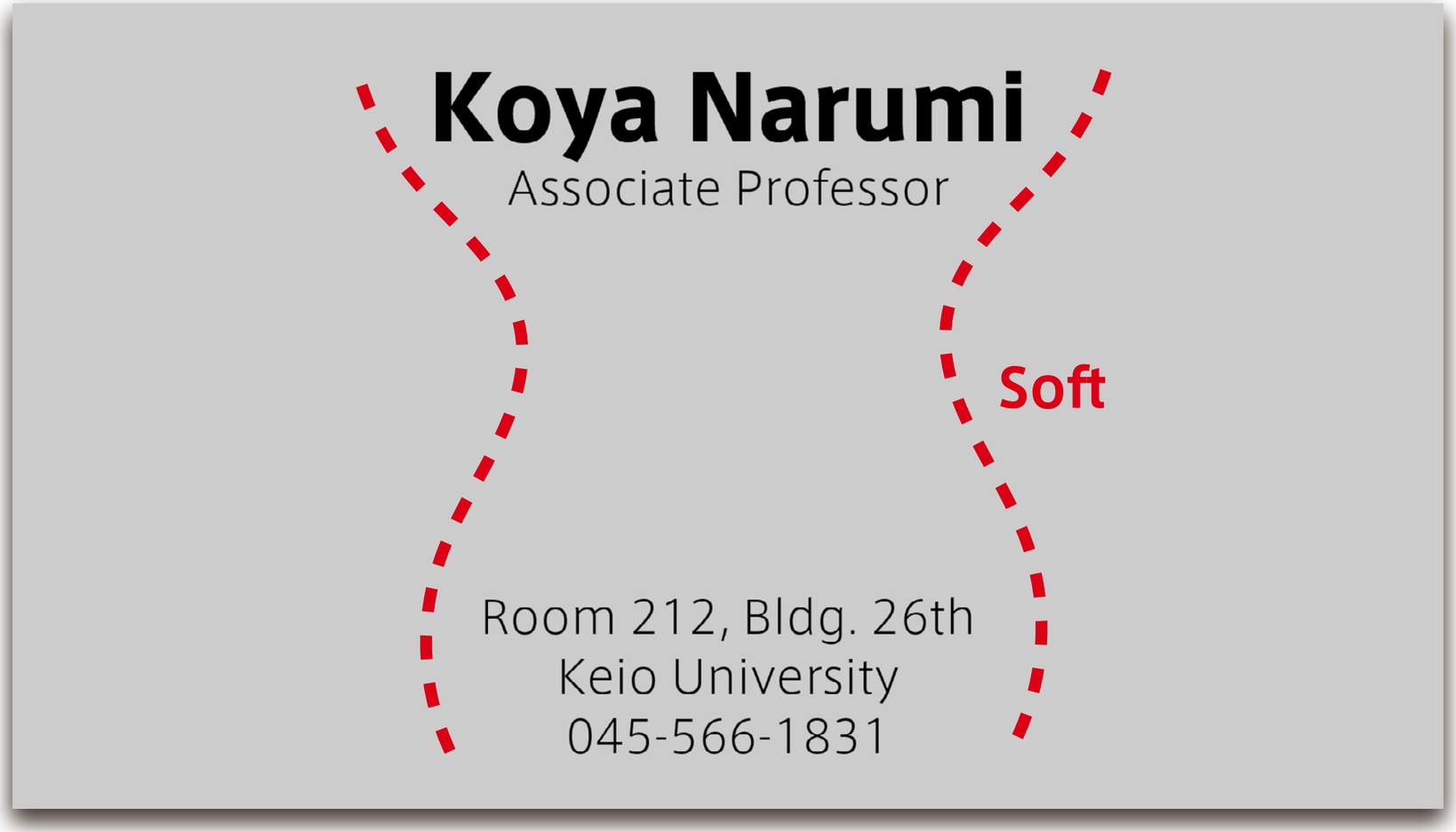


Concepts are cited from "The Non-Designer's Design Book"

Alignment: Name Card

Concepts are cited from "The Non-Designer's Design Book"

Alignment: Name Card

Strong line

Concepts are cited from "The Non-Designer's Design Book"

Alignment: Name Card

OK

Better

Much better

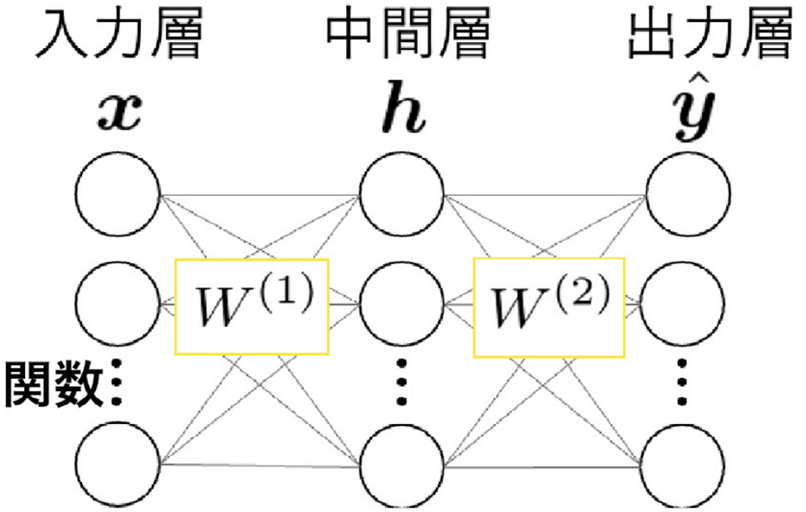
Invisible lines should be as clear and few as possible.

Concepts are cited from "The Non-Designer's Design Book"

Alignment: Slides (1)

モデル

- 入力：28x28ピクセル画像
- 出力：10次元（0～9のラベルに対応）
- ニューラルネット：3層のFFNN
- 中間層の活性化関数：ReLu
- 中間層のユニット数：128
- 出力層の活性化関数：Softmax
- 損失関数：交差エントロピー誤差関数：
- 最適化手法：ミニバッチSGD



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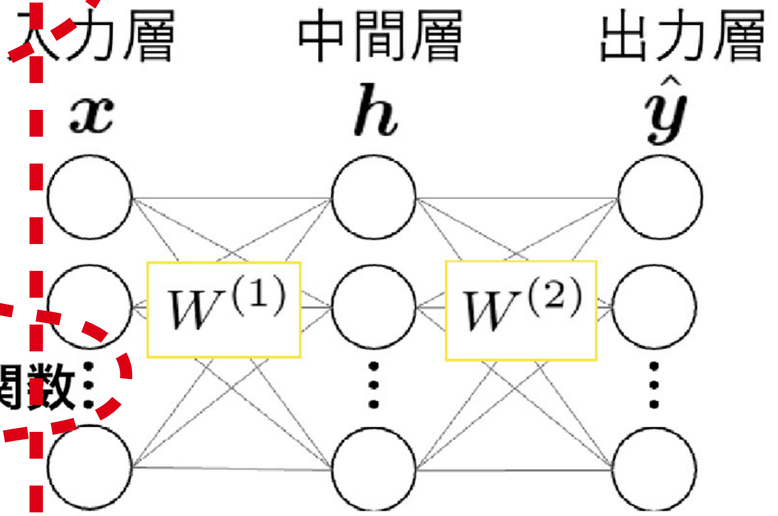

Intersecting lines

Alignment: Slides (1)

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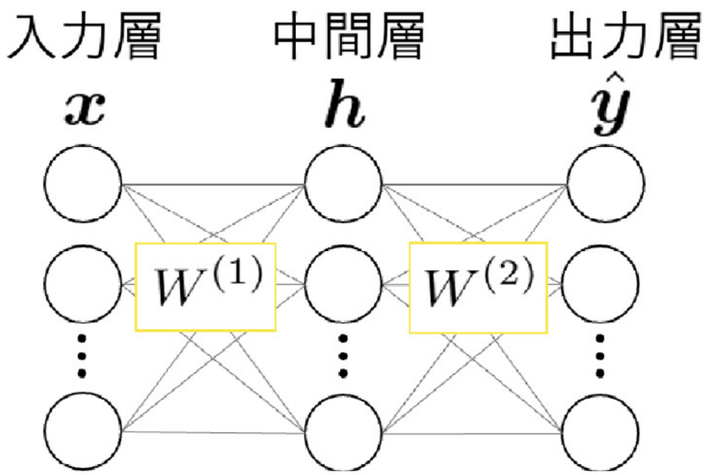

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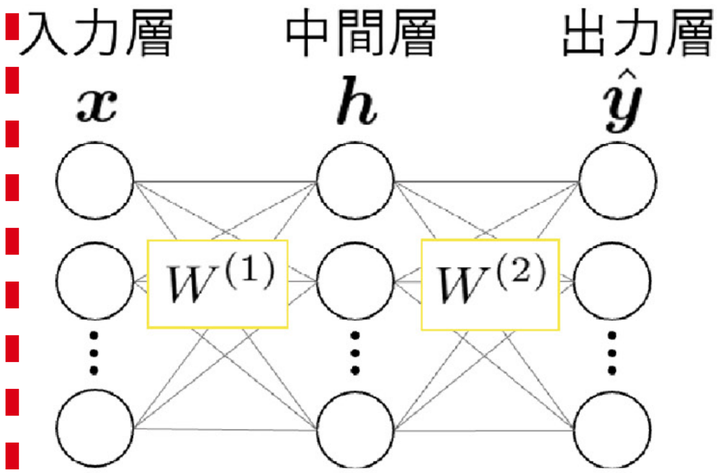

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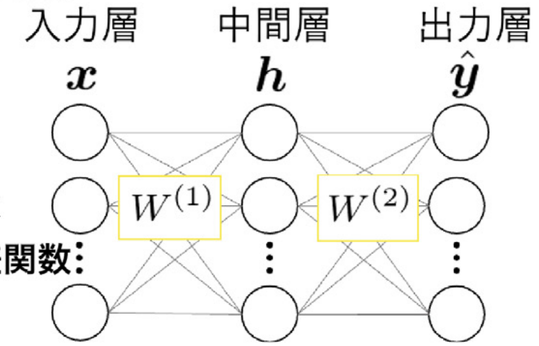

OK

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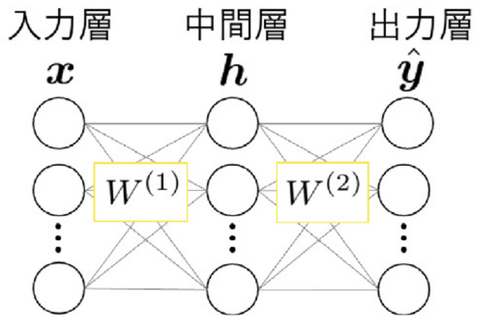

Better

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Concepts are cited from “The Non-Designer’s Design Book”

Alignment: Slides (2)

Bio

東京大学 工学部 電子情報工学科 卒業

東京大学 大学院工学系研究科 修士課程

日本学術振興会特別研究員（DC1）

JSPS ACT-I「情報と未来」個人研究者

東京大学 大学院情報理工学系研究科 博士課程

東京大学 大学院情報学環 助教

東京大学 大学院工学系研究科 特任講師

慶應義塾大学 理工学部 准教授

Alignment: Slides (2)

Bio

東京大学 工学部 電子情報工学科 卒業

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慶應義塾大学 理工学部 准教授

Alignment: Slides (2)

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東京大学 大学院情報学環 助教

東京大学 大学院工学系研究科 特任講師

慶應義塾大学 理工学部 准教授

Alignment: Slides (2)

Bio

東京大学 工学部 電子情報工学科 卒業
東京大学 大学院工学系研究科 修士課程
日本学術振興会特別研究員（DC1）
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OK

Bio

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慶應義塾大学 理工学部 准教授

Better

Invisible lines should be as clear and few as possible.

Concepts are cited from “The Non-Designer’s Design Book”

Please do not aimlessly
use center-aligned texts.
It automatically increases
the amount of invisible lines.
Consider left- / right- aligned
texts as default.

Concepts are cited from “The Non-Designer’s Design Book”

Please do not aimlessly
use center-aligned texts.
It automatically increases
the amount of invisible lines.
Consider left- / right- aligned
texts as default.

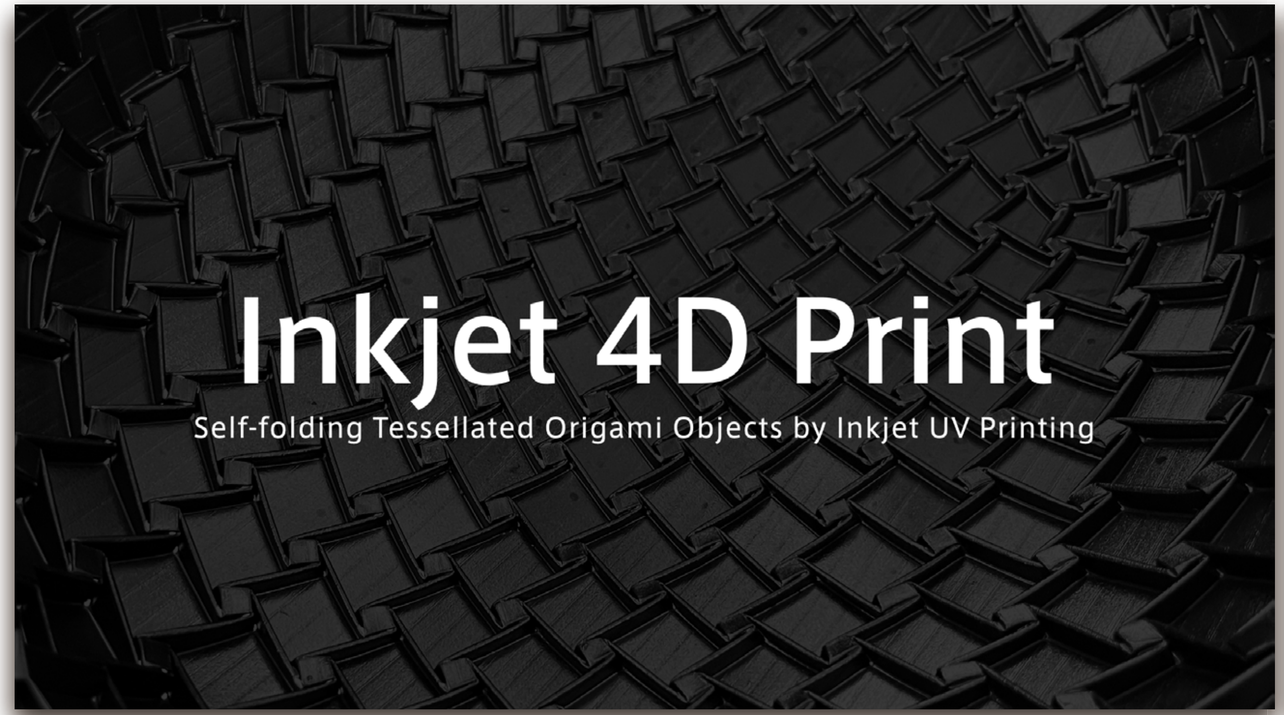
Concepts are cited from “The Non-Designer’s Design Book”

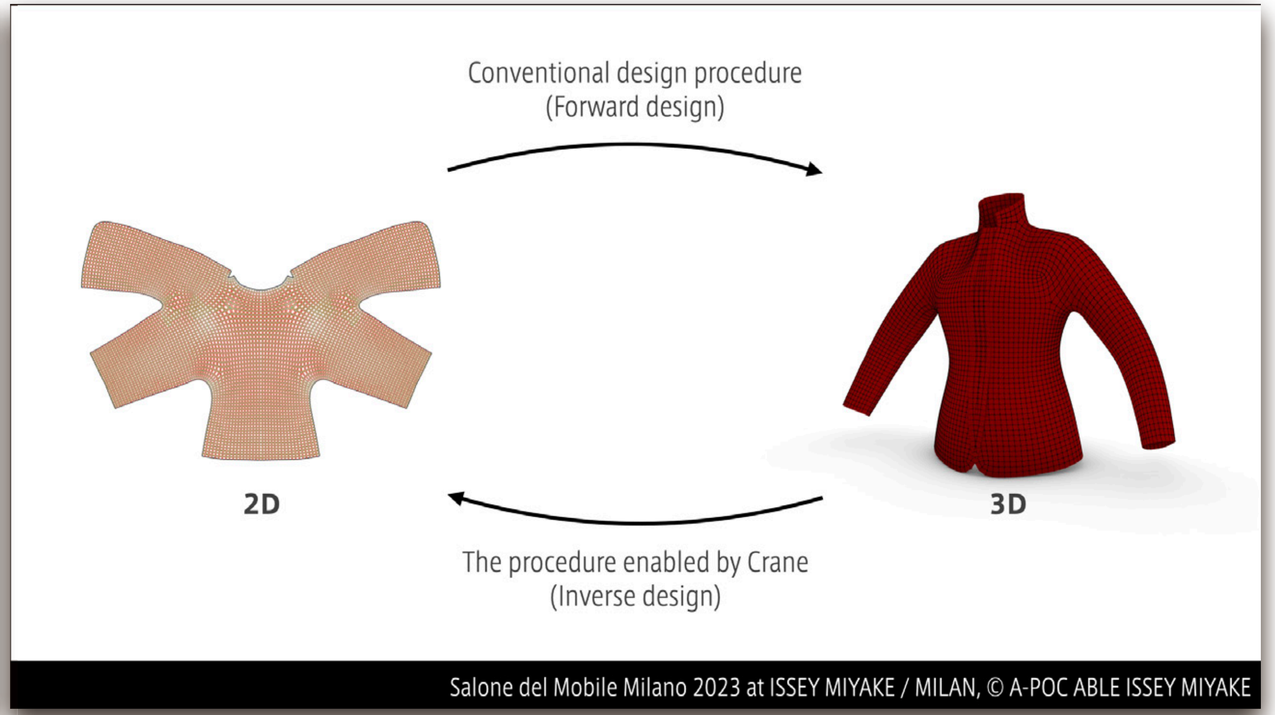
In short,

Try not using center-aligned texts.

Concepts are cited from “The Non-Designer’s Design Book”

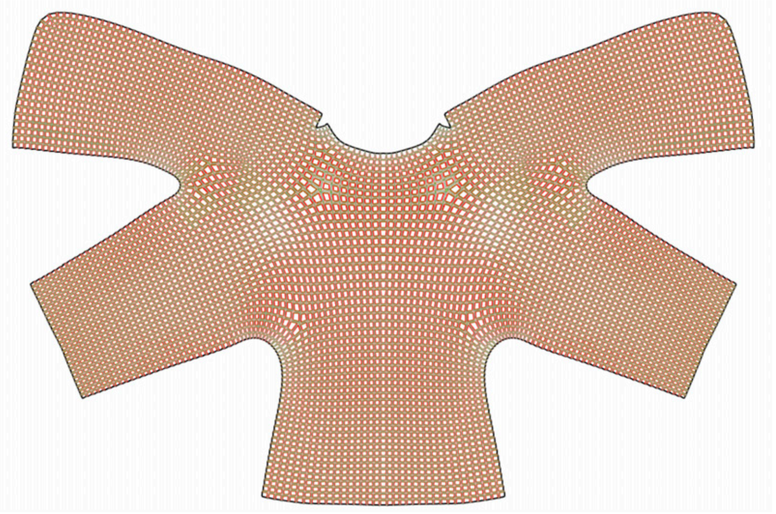
NOTE: Center-aligned texts are **NOT Always Bad**





Properly designed center-aligned texts are formal and powerful.

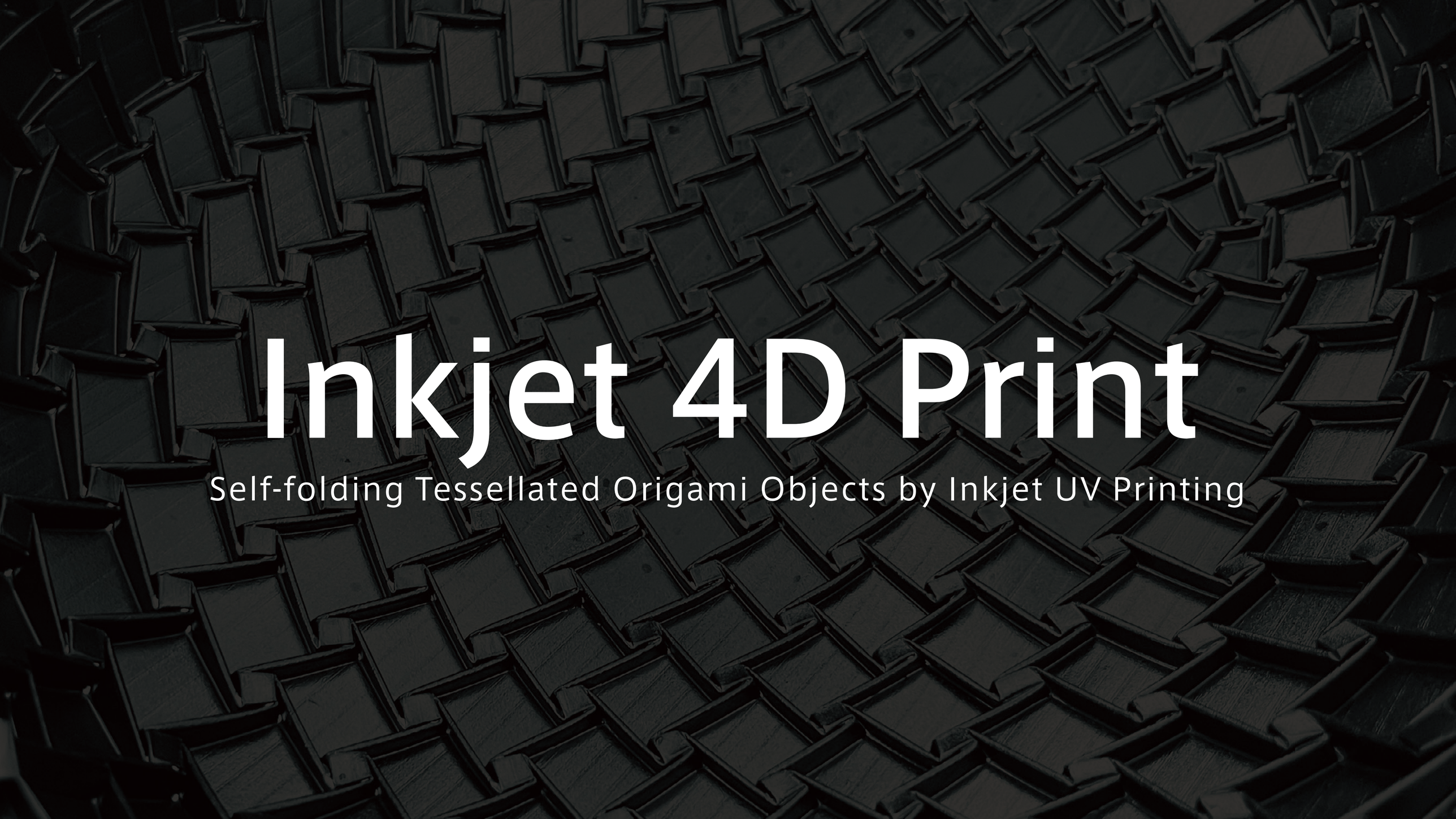
Conventional design procedure
(Forward design)



2D

3D

The procedure enabled by Crane
(Inverse design)



Inkjet 4D Print

Self-folding Tessellated Origami Objects by Inkjet UV Printing

Four Design Principles as **Basics**

Proximity

Related contents must be **close**. **Unrelated contents** must be **far.**

Alignment

Invisible lines should be as **clear and few** as possible.

Repetition

Repeated concepts improves **consistency.**

Contrast

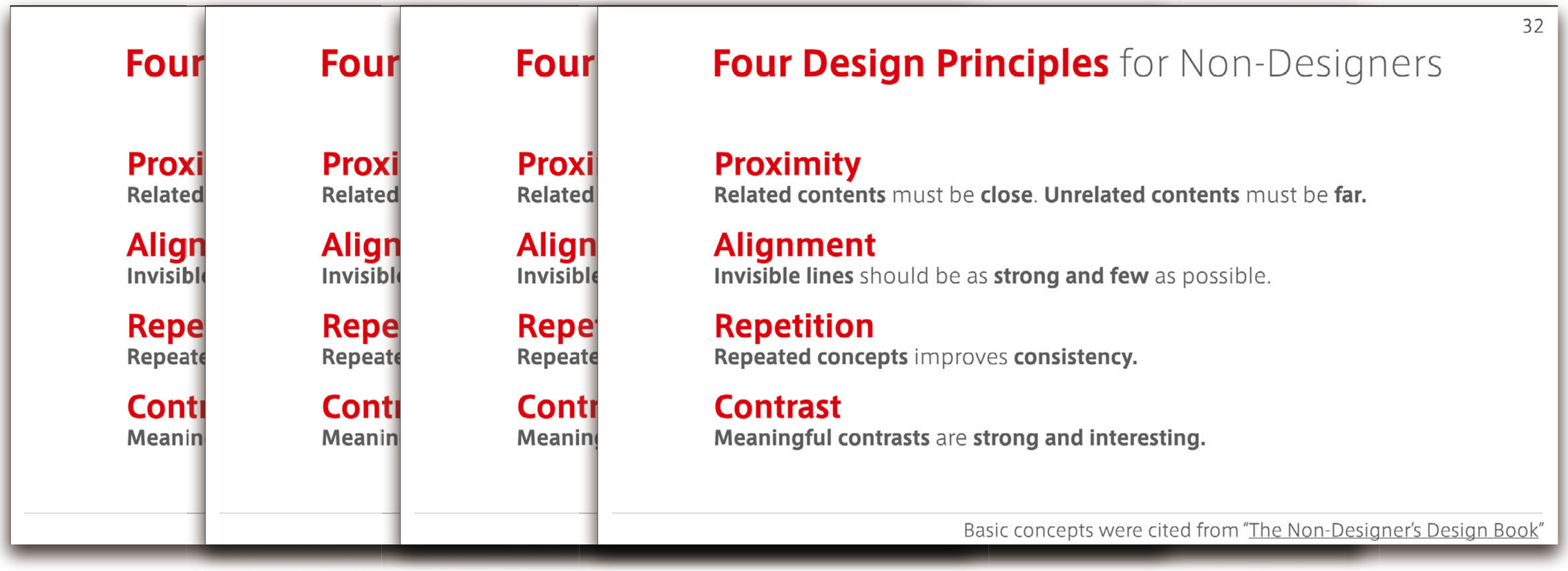
Meaningful contrasts are **strong rather than subtle.**

Concepts are cited from "The Non-Designer's Design Book"

REPETITION

Repeated concepts improves consistency

Repeated contents tell **where you are**

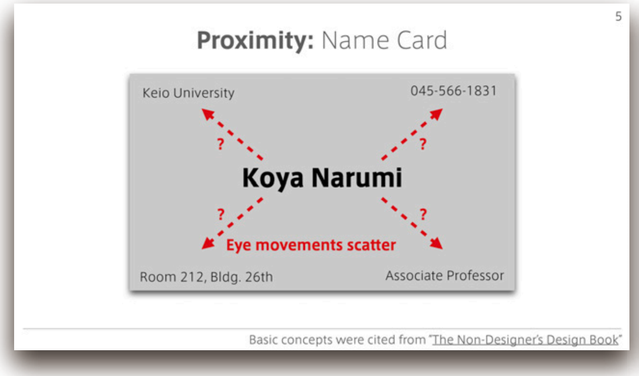


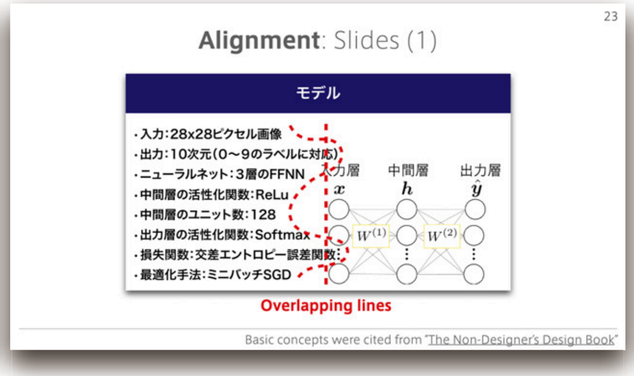
Don't hesitate to use the same slide as **a table of contents.**

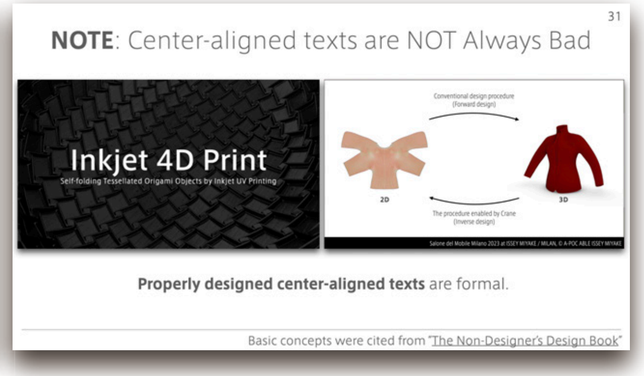
Repeated contents tell **where you are**

Don’t hesitate to use the same slide as **a table of contents.**

Repeated structure guarantees **consistency**







From the same structure, people can tell that **slides deal with similar topics**.

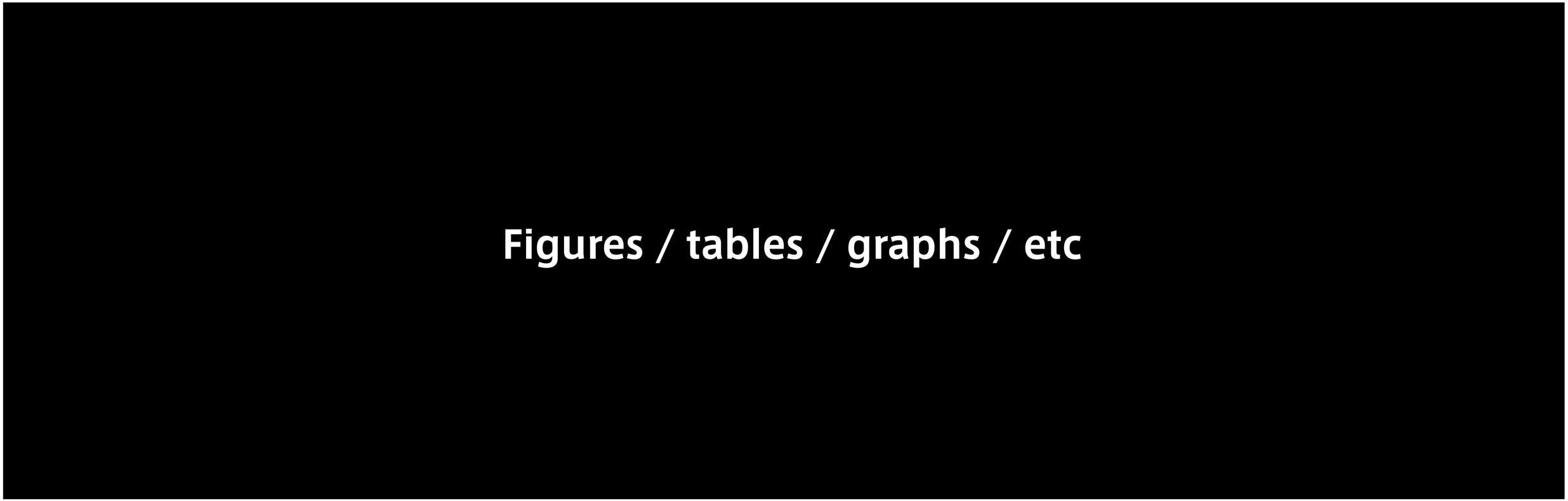
Example template

Figures / tables / graphs / etc

Conclusions are here.
Conclusions are here.

Title → # Example template

Page number



Citation grid

Conclusions are here.
Conclusions are here.

← Conclusions

Citation place

Example template

Never change the height

Never change the height

Never change the height

Conclusions are here.

Conclusions are here.

If You Do Not Strictly Repeat Structures

Figures / tables / graphs / etc

Conclusions are here.
Conclusions are here.

If You Do Not Strictly Repeat Structures

Figures / tables / graphs / etc

Conclusions are here.

Conclusions are here.

Subtle movements are quite annoying.
keep pixel-perfect.

Even if the objects change like this, keep pixel-perfect.

Four Design Principles as **Basics**

Proximity

Related contents must be **close**. **Unrelated contents** must be **far.**

Alignment

Invisible lines should be as **clear and few** as possible.

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Contrast

Meaningful contrasts are **strong rather than subtle.**

Concepts are cited from "The Non-Designer's Design Book"

CONTRAST

Meaningful contrasts are strong rather than subtle

Failure of font size contrasts

- The default setup of
  - PowerPoint somehow changes the font size
    - very slightly for each intdentation level (by 2pt)
      - This has almost no contrast.

Change drastically, or **don't change**

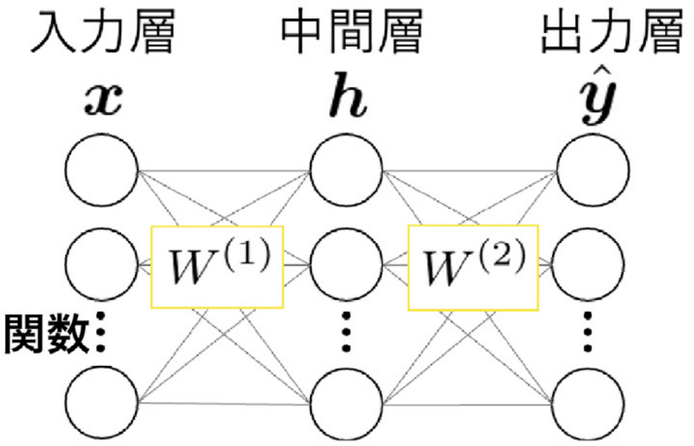
- Change the font size drastically if you have some intention.
- Subtle change is imperceptible and looks inconsistent.

Concepts are cited from "The Non-Designer's Design Book"

Don’t Emphasize Everything

モデル

- 入力：28x28ピクセル画像
- 出力：10次元（0～9のラベルに対応）
- ニューラルネット：3層のFFNN
- 中間層の活性化関数：ReLu
- 中間層のユニット数：128
- 出力層の活性化関数：Softmax
- 損失関数：交差エントロピー誤差関数
- 最適化手法：ミニバッチSGD



“A curse of large fonts” taught by your advisors.

Designers use **small fonts** or **white space** as well to better contrast.

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モデル

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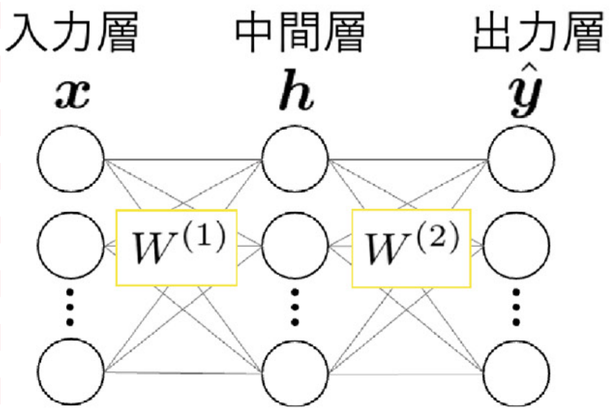
- 損失関数：交差エントロピー誤差関数
- 最適化手法：ミニバッチSGD

Appropriate space



“A curse of large fonts” taught by your advisors.

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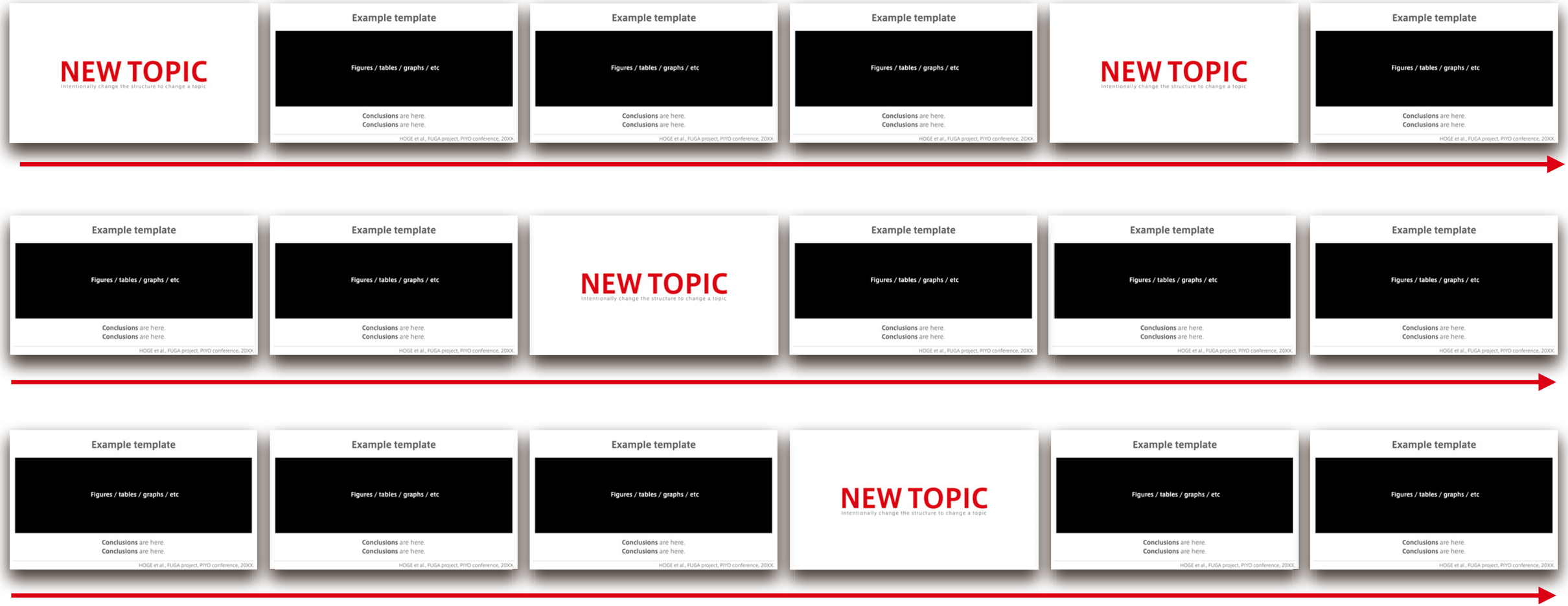
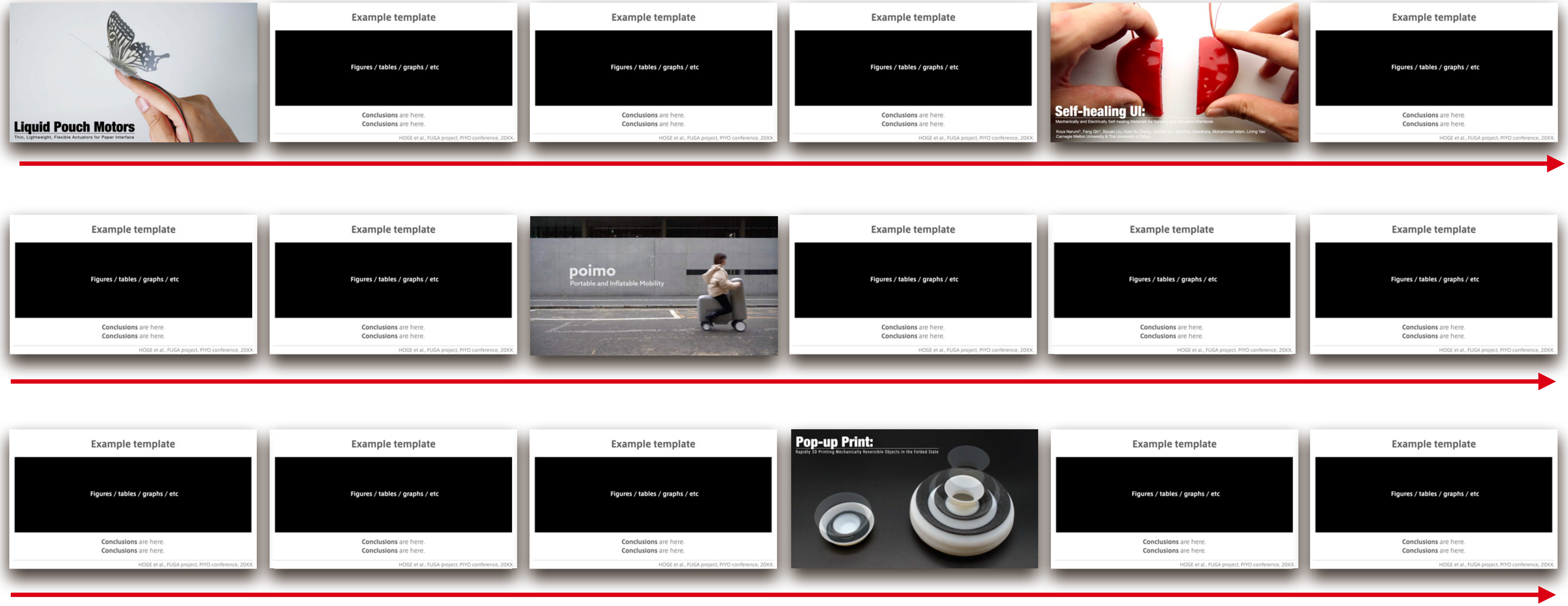
Change the **Structure** to Start a **New Topic**



Change the **Structure** to Start a **New Topic**



Basic

守

Advanced

展

Four Ideas as **Advances**

Animation

Audience **cannot help** watching animation.

Backgrounds

Effectively use the **meaning of backgrounds.**

Eye Motion

Grasp the **instant eye motion** of audience.

Aspect Ratio

We can actually select **any aspect ratio as curiosity allows**.

ANIMATION

Audience cannot help watching animation

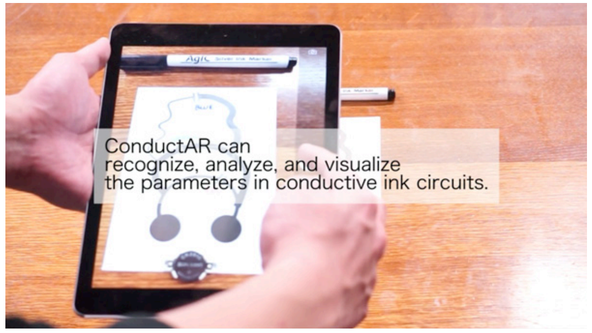
Animation is Powerful for Eye Motion Control

After all, we are **mantes** following animation.

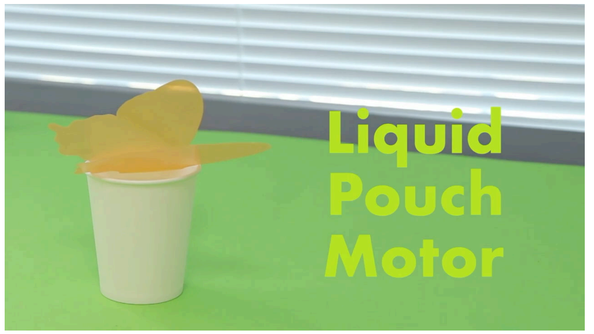
---

https://commons.wikimedia.org/wiki/File:Rhombodera_basalis_1_Luc_Viatour.jpg#/media/%E3%83%95%E3%82%A1%E3%82%A4%E3%83%AB:Rhombodera_basalis_1_Luc_Viatour.jpg

Circuit Eraser
ACM CHI EA 2015, Kickstarter



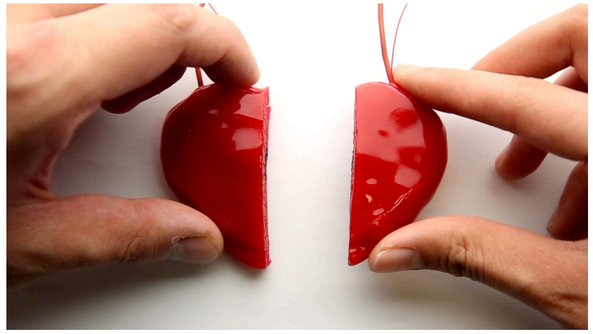
ConductAR
ACM UbiComp 2016



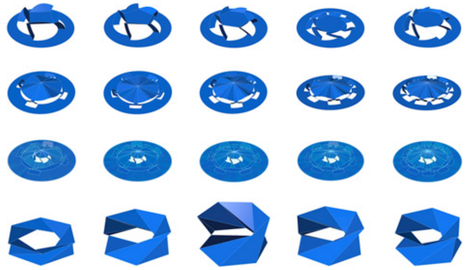
Liquid Pouch motors
IEEE ICRA 2017, IEEE RA-L 2020

Papilion
Ars Electronica 2017

A LIVE UN LIVE
六本木クロッシング 2018



Self-healing UI
ACM UIST 2019

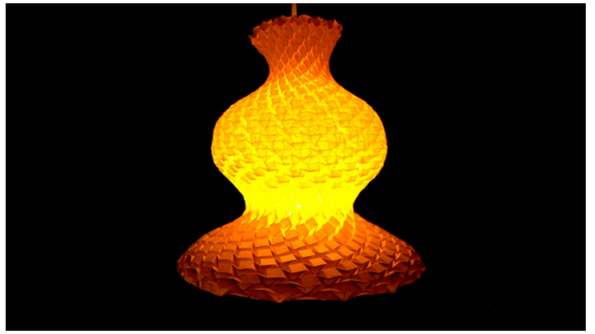


Kirigami Haptic Swatches
ACM CHI 2020

Pop-up Print
ACM UIST 2020

poimo
ACM UIST 2020

Flower Jelly Printer
ACM CHI 2021



Crane
ACM TOCHI (CHI) 2023

Inkjet 4D Print
ACM TOG (SIGGRAPH) 2023

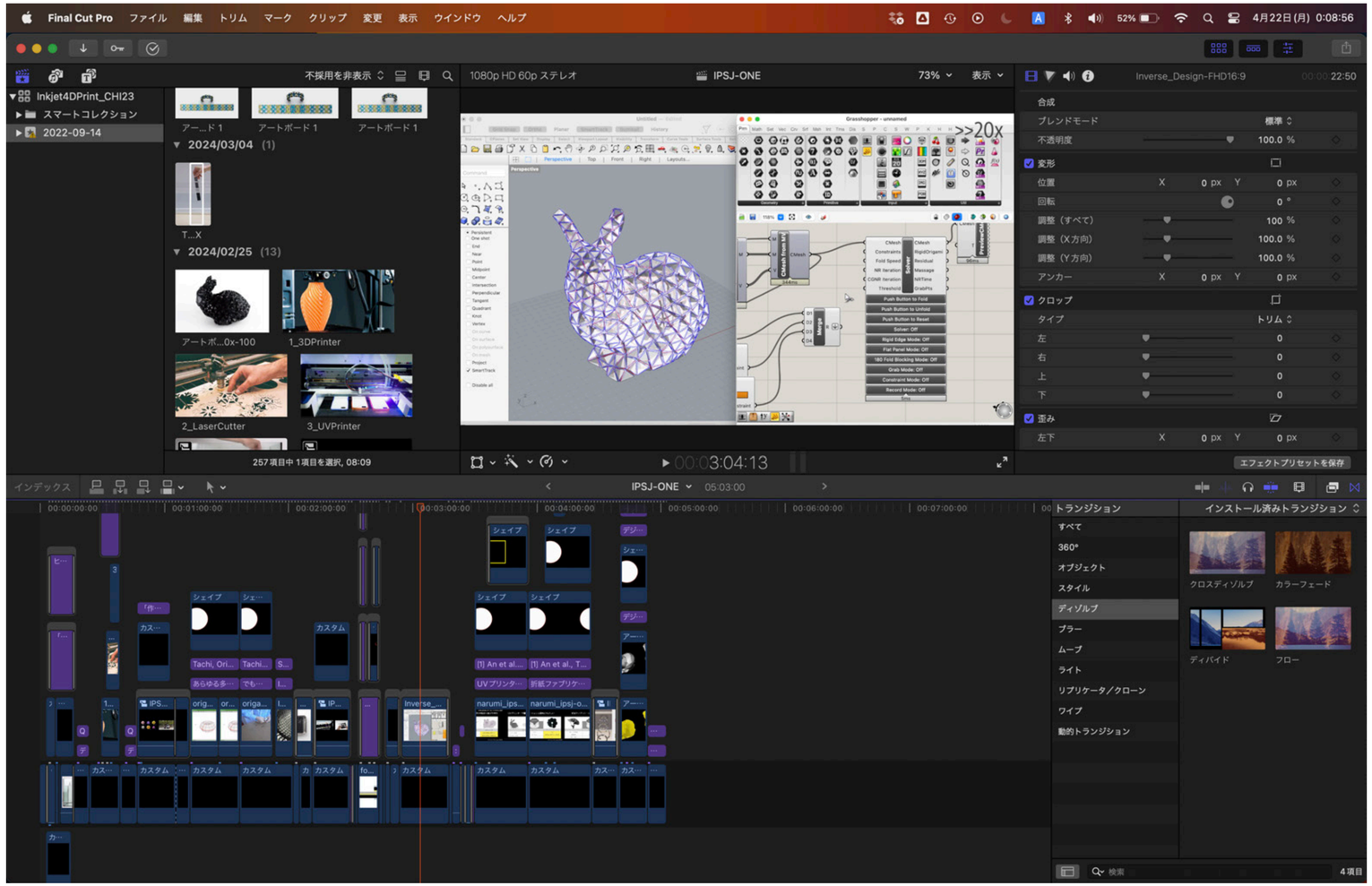
「作り方を作る」デジタルファブリケーション

Making “how to make” by Digital Fabrication

Language = Japanese, duration = 5 min
IPSJ-ONE2024
https://youtu.be/Nhkpcyvwbw0?t=5106

2024.3.16 [Sat]
情報処理学会 第86回全国大会
神奈川大学横浜キャンパス

Video Presentation is **not** Practical



But Two Tricks are Cost-effective

Translucent transition

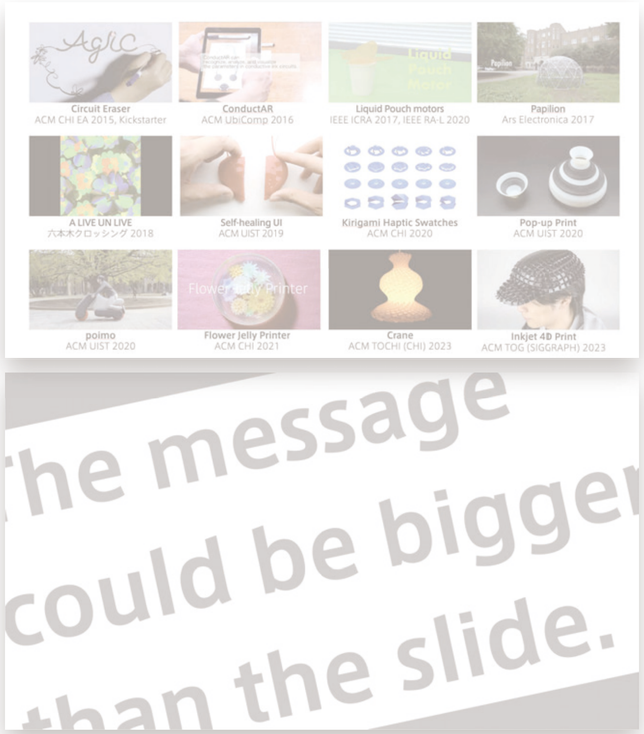
Opening animation

follow

守

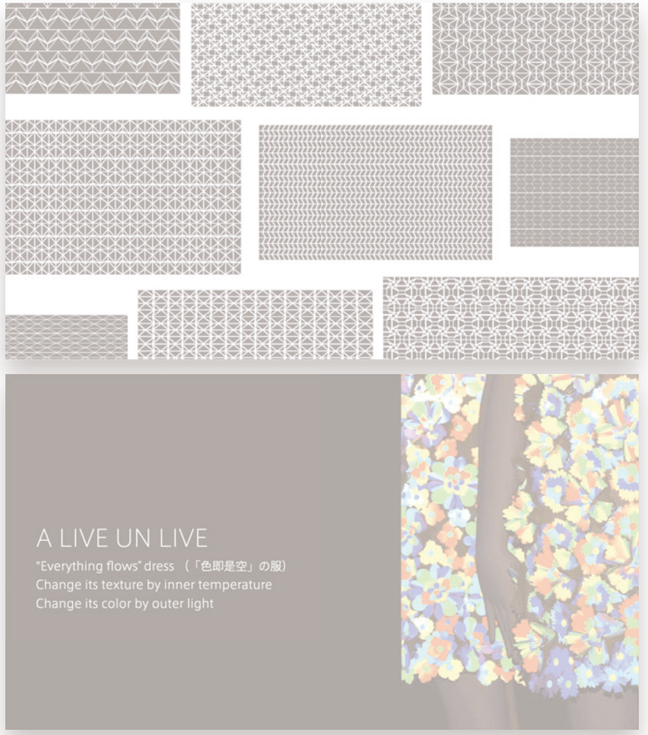
Break

破



Don't care

離



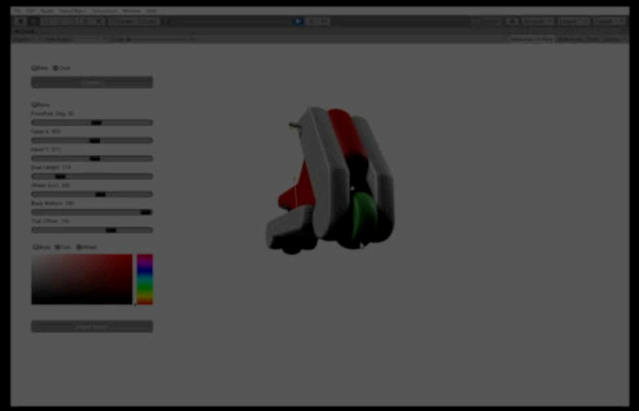
[1] https://tsutawarudesign.com/

Translucent Transition

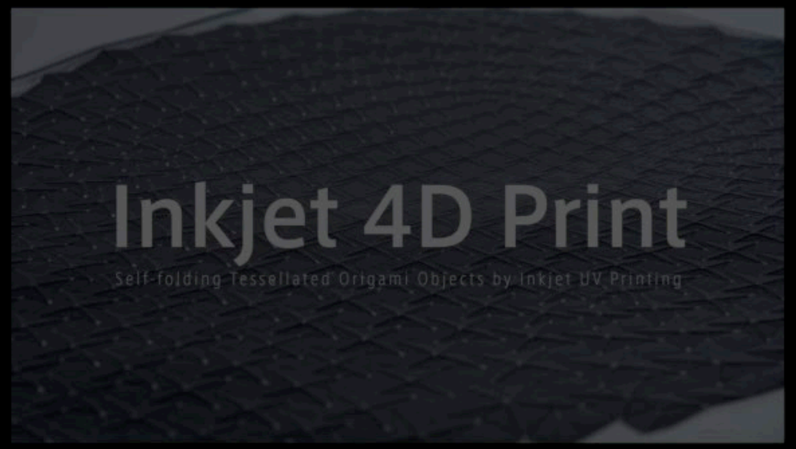
Transition effect helps audience **follow the topic**.
Transparency helps audience **predict the story**.

「作り方」を作る

ゼリーの中に**ゼリー**を
3Dプリントする方法



自分だけの**モビリティ**を
作る方法



どんな形の**折紙**でも
自動で折る方法

But Two Tricks are Cost-effective

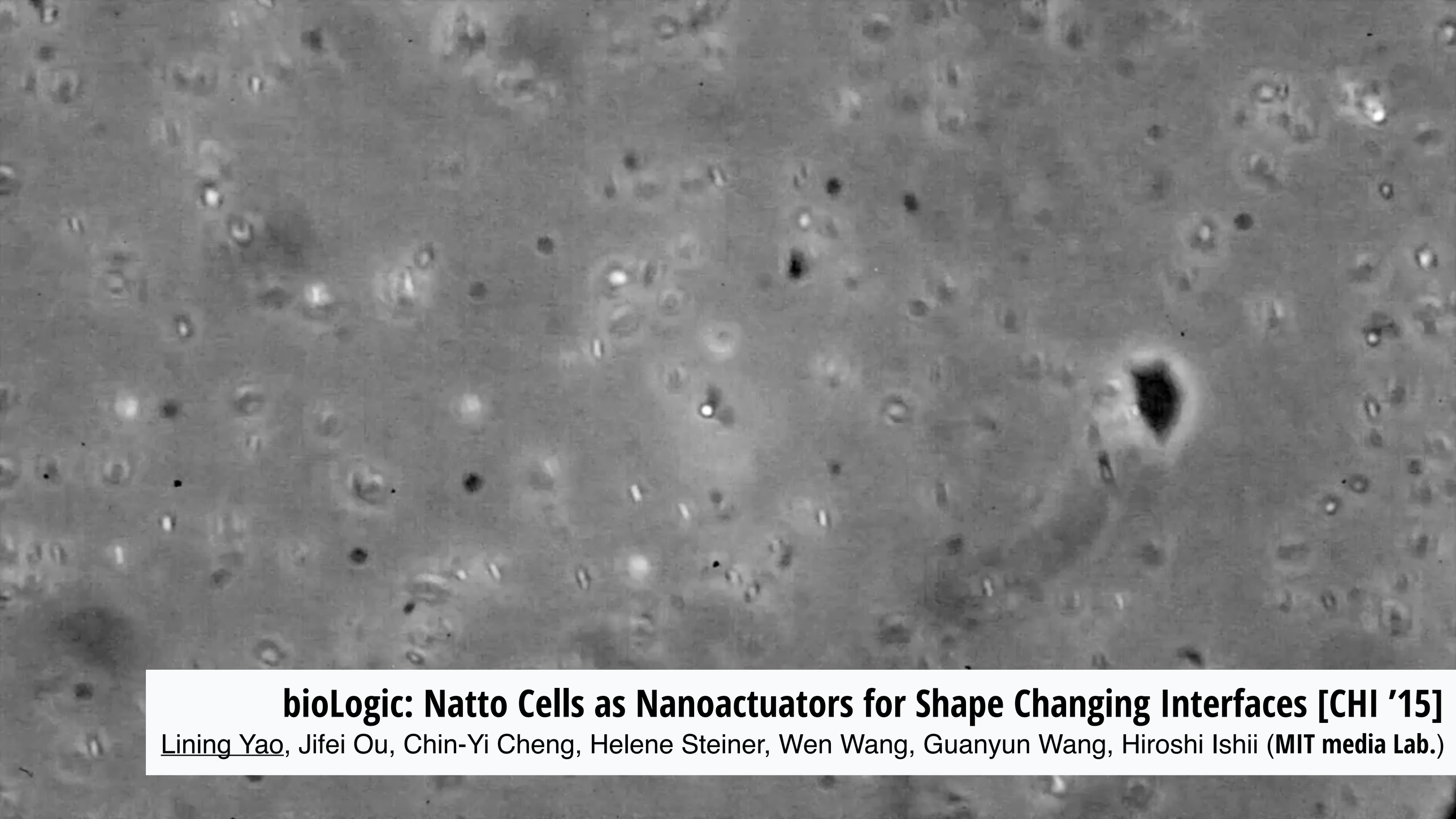
Translucent transition

Opening animation

Opening Animation

Audience lose their interests in the first 30 sec of the talk.

Opening animation communicates **even before the presentation**.



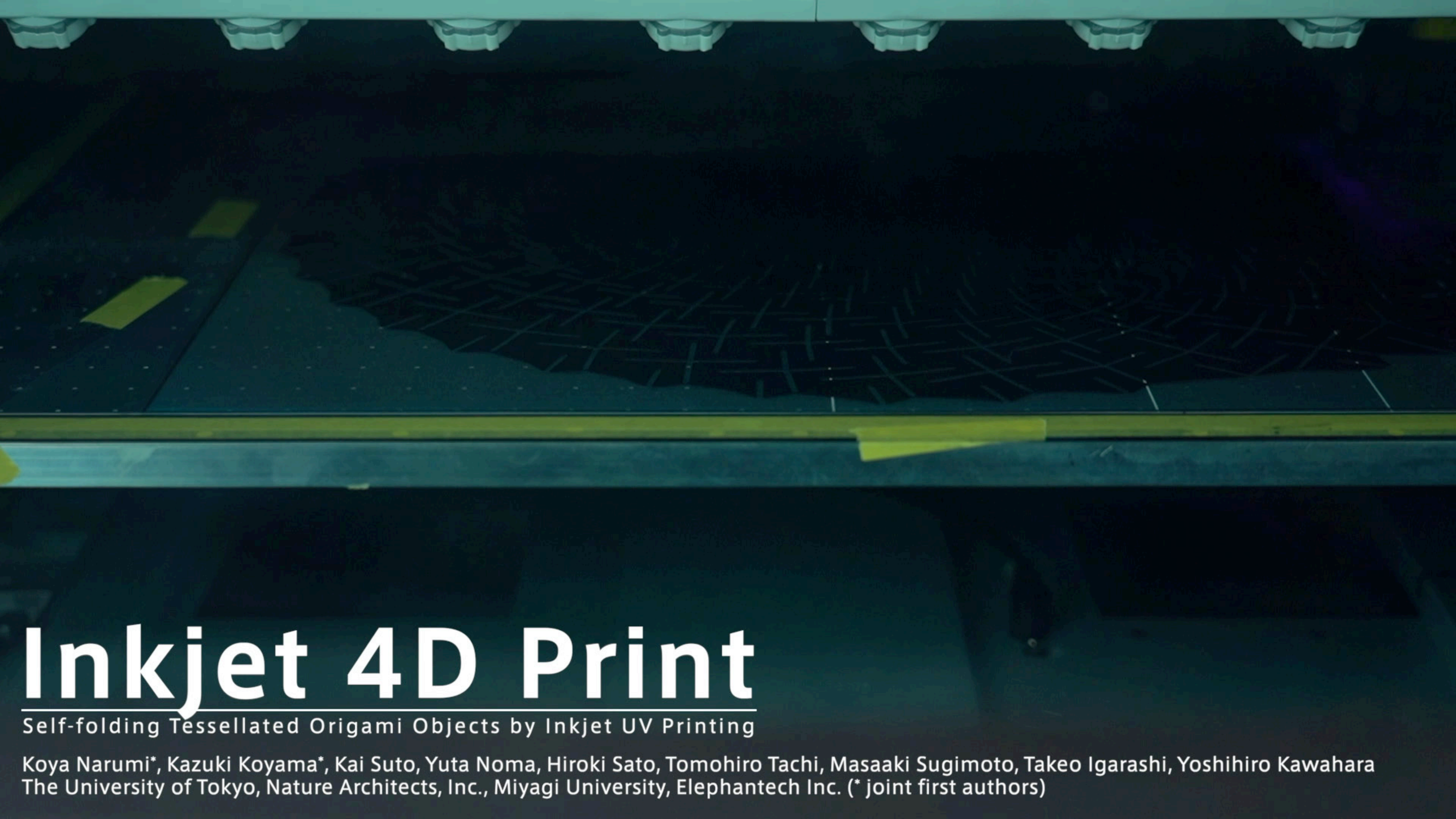
bioLogic: Natto Cells as Nanoactuators for Shape Changing Interfaces [CHI '15]

Lining Yao, Jifei Ou, Chin-Yi Cheng, Helene Steiner, Wen Wang, Guanyun Wang, Hiroshi Ishii (**MIT media Lab.**)

Self-healing UI:

Mechanically and Electrically Self-healing Materials for Sensing and Actuation Interfaces

Koya Narumi*, Fang Qin*, Siyuan Liu, Huai-Yu Cheng, Jianzhe Gu, Yoshihiro Kawahara, Mohammad Islam, Lining Yao
Carnegie Mellon University & The University of Tokyo



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)

Opening Animation

Audience lose their interests in the first 30 sec of the talk.

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Four Ideas as **Advances**

Animation

Audience **cannot help** watching animation.

Backgrounds

Effectively use the **meaning of backgrounds.**

Eye Motion

Grasp the **instant eye motion** of audience.

Aspect Ratio

We can actually select **any aspect ratio as curiosity allows**.

BACKGROUNDS

Effectively use the meaning of backgrounds

In short,

I recommend novices using white backgrounds

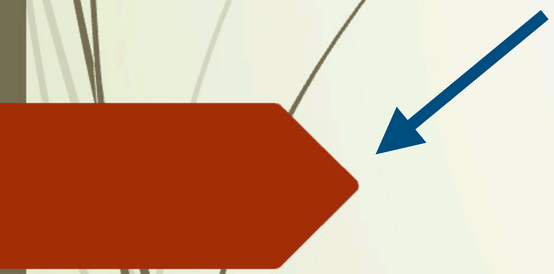
Concepts are cited from “The Non-Designer’s Design Book”

Do not rely on **meaningless and run-of-the-mill decoration.**

If you hope to use it, choose a meaningful one

Do not rely on **meaningless and run-of-the-mill decoration.**

If you hope to use it, choose a meaningful one



Do not rely on **meaningless and run-of-the-mill decoration.**

If you hope to use it, choose a meaningful one

White Background

Pros

Many type of figures are available
Clean and easy

Cons

Black Background

Pros

Serious atmosphere.
High-contrast images.

Cons

Photos with colored backgrounds are typically not suitable.

Reconfigurable Actuator

“C” curve

“S” curve

Short “C” curve

形状と動きを**再構成可能**なアクチュエータ

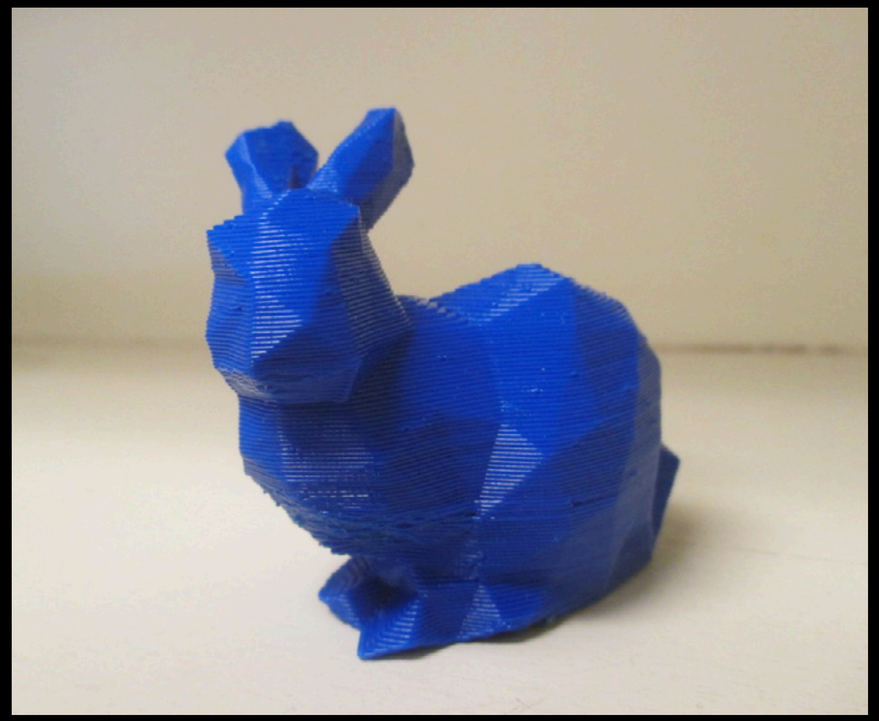
A LIVE UN LIVE

"Everything flows" dress （「色即是空」の服）

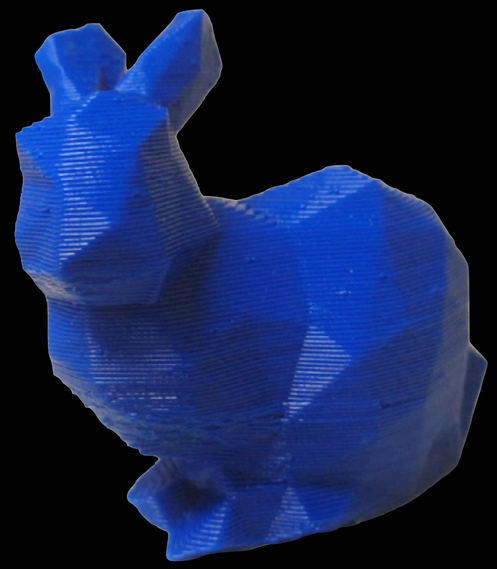
Change its texture by inner temperature

Change its color by outer light

Black Background



OK



Better, but time-consuming

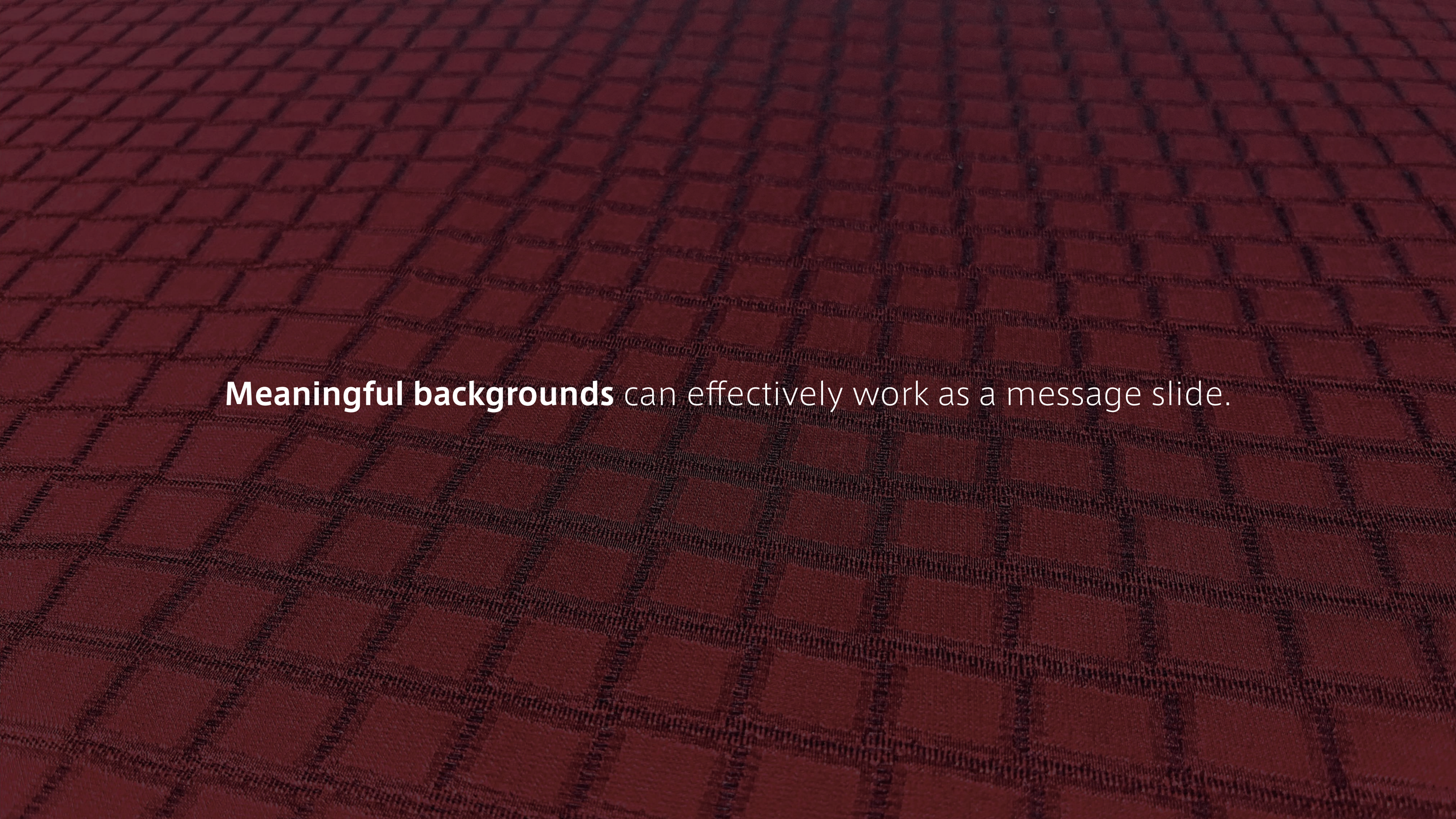
Textured Background

Pros

Easier to communicate the story.

Cons

Noisy and less useful for informative slides.


Meaningful backgrounds can effectively work as a message slide.

There are many fabrication papers published in CHI every year,

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

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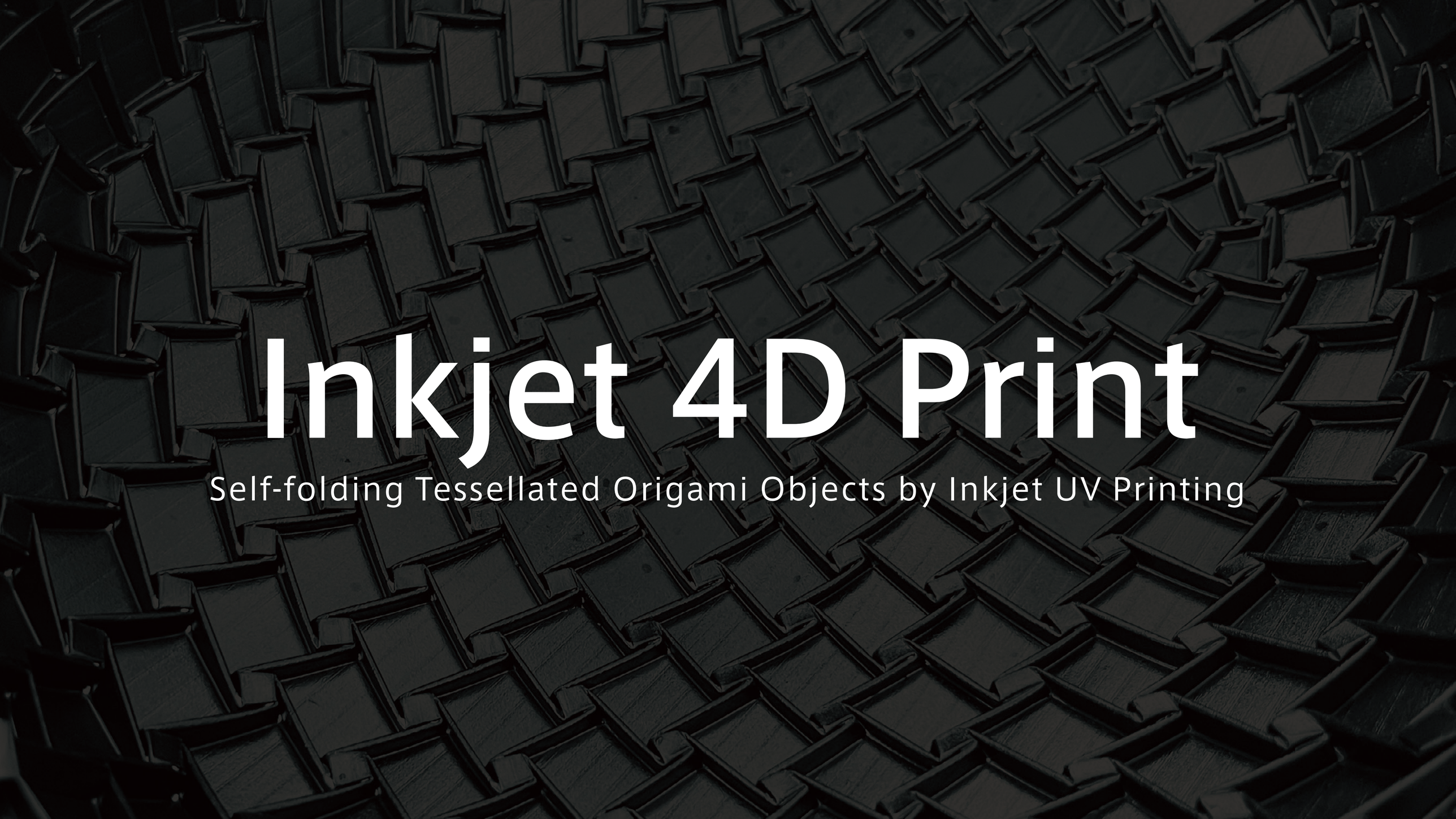
but we are proud of our paper **applied to the REAL design and industry.**



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Four Ideas as **Advances**

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Aspect Ratio

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EYE MOTION

Grasp the instant eye motion of audience

In short,

Be conscious of the natural eye motion of audience.

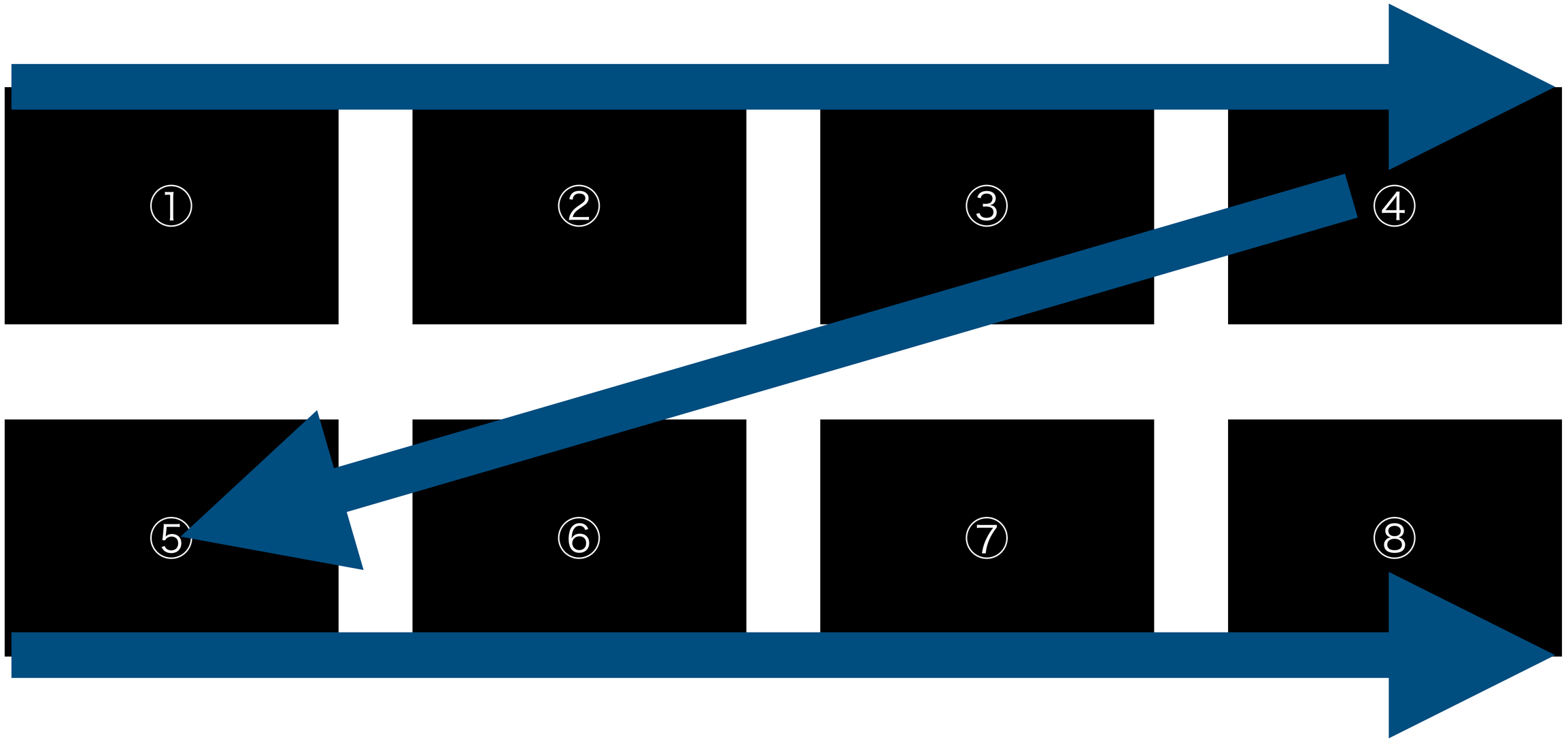
In which order do you gaze at them?








“Z” shape is known to be natural



Don’t Use “コ” shape

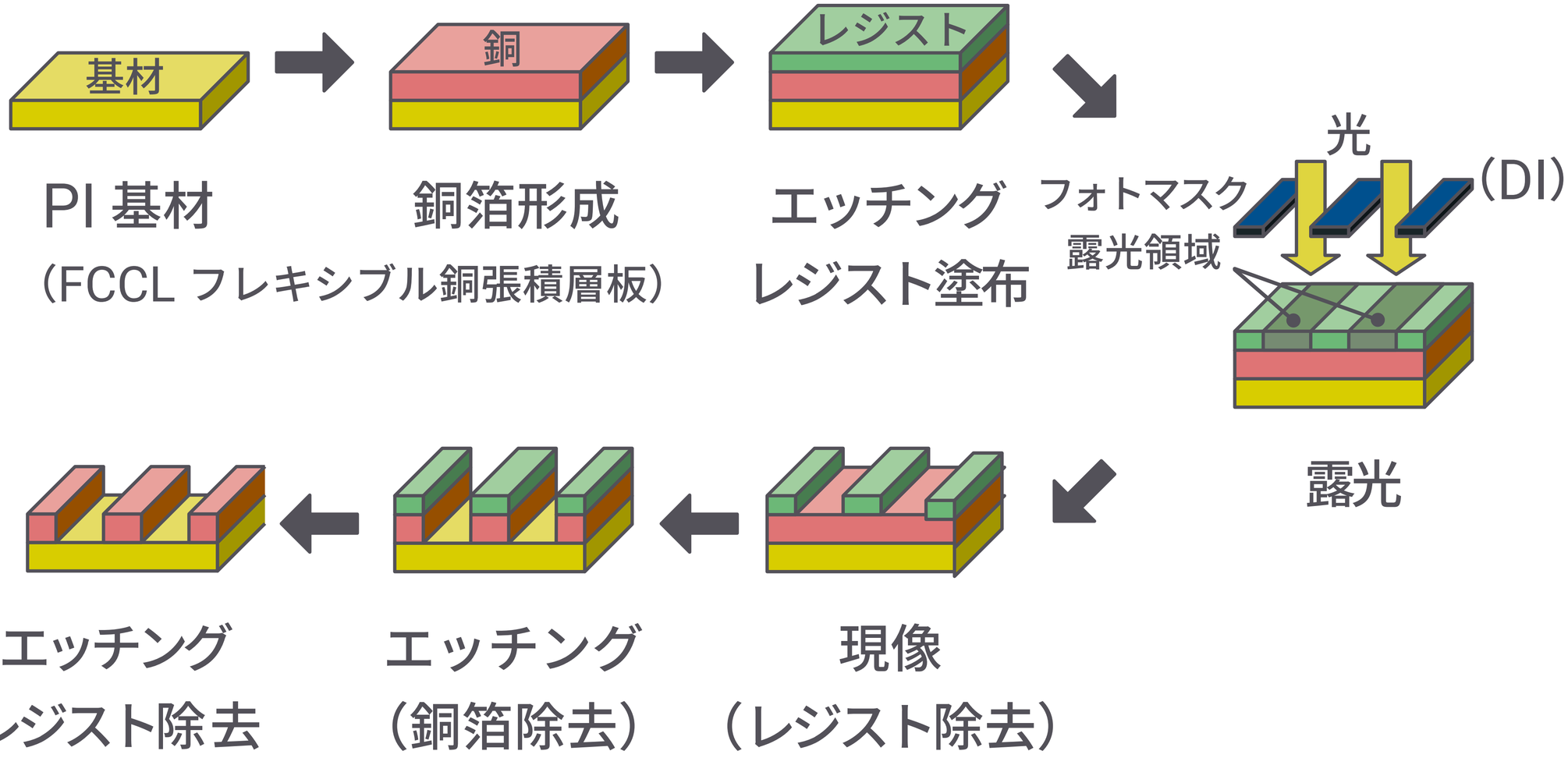


Figure was cited from Elephantech and intentionally modified worse from a beautiful version.

Don’t Use “コ” shape

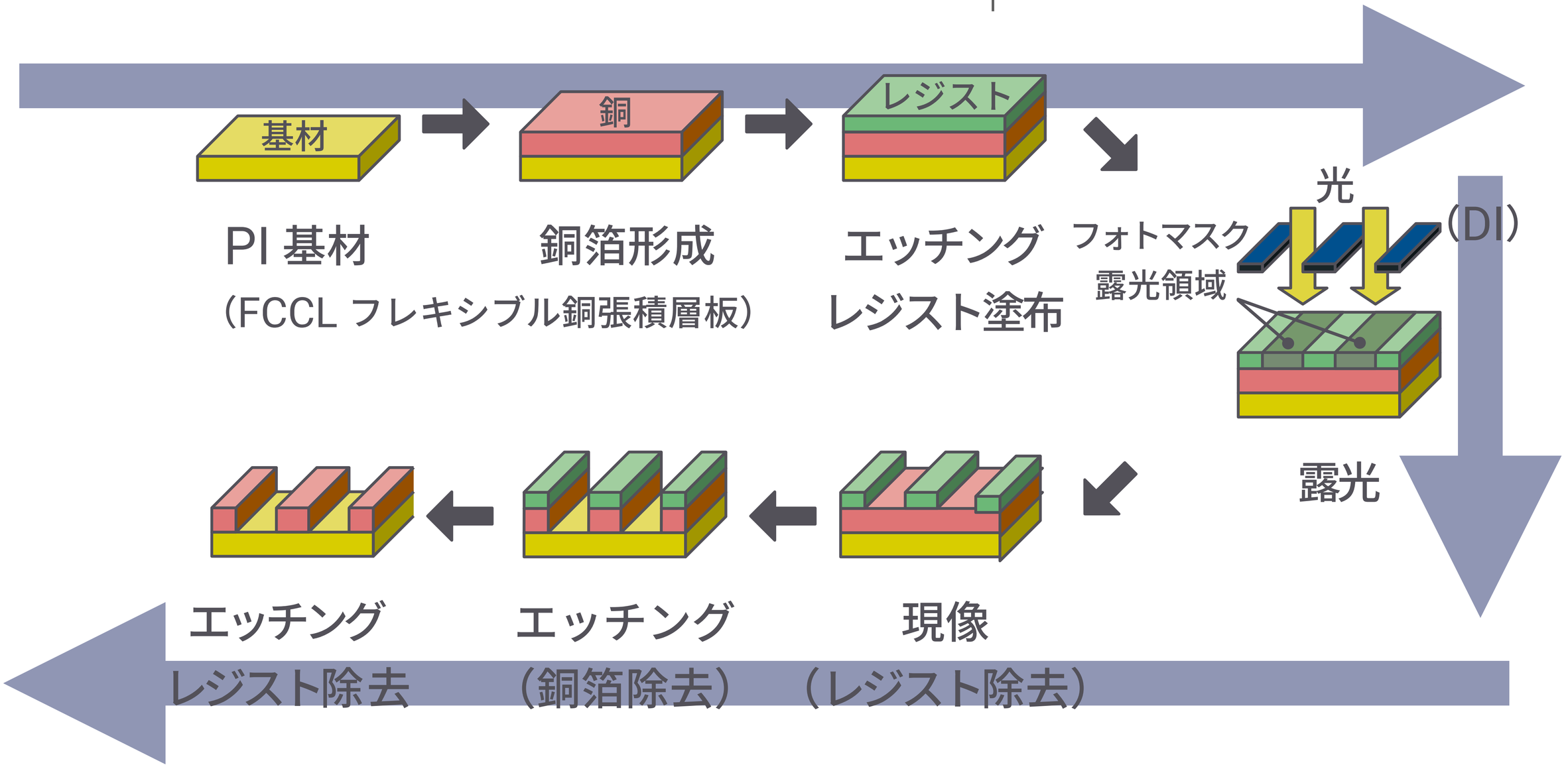


Figure was cited from Elephantech and intentionally modified worse.

Otherwise, animation could be useful

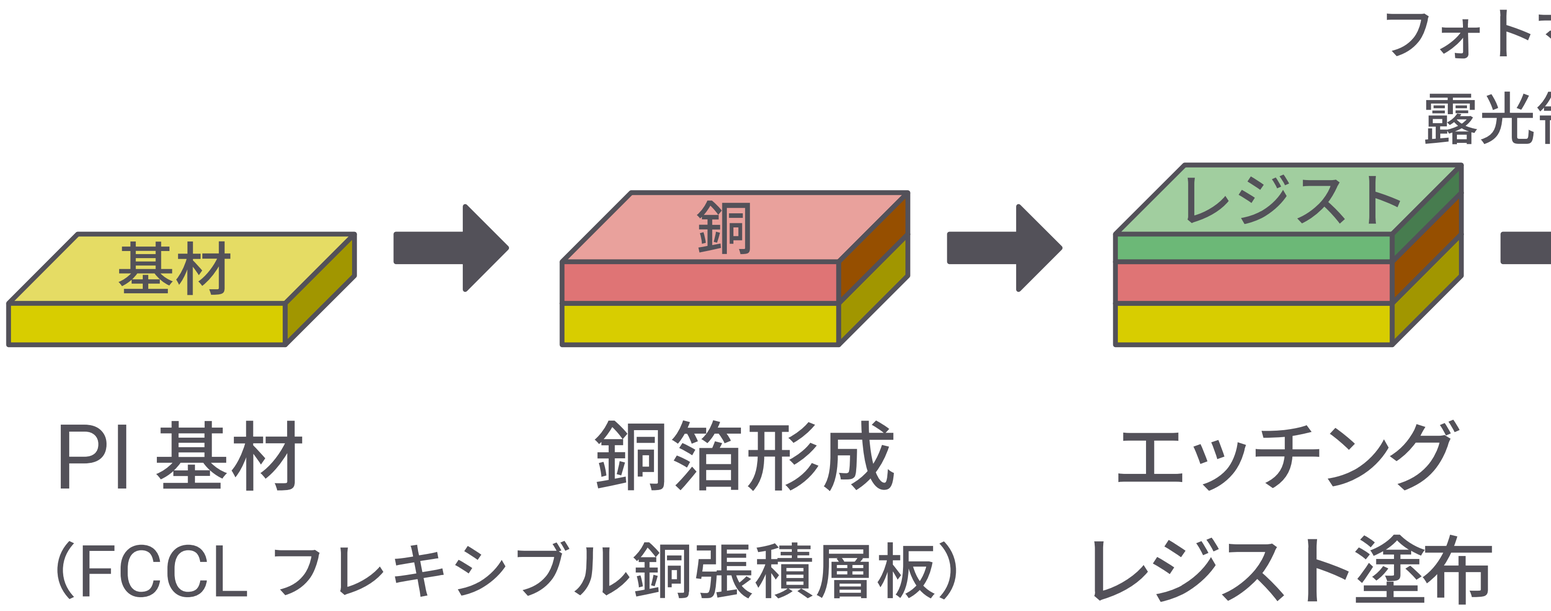
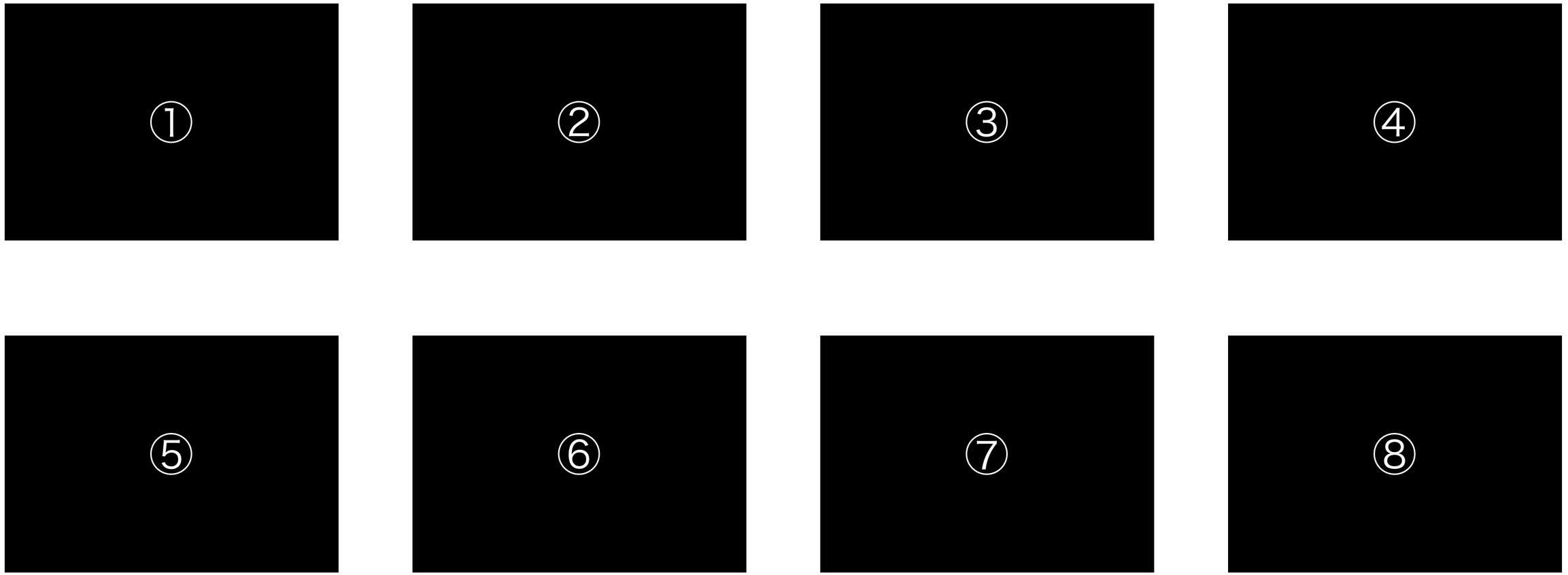
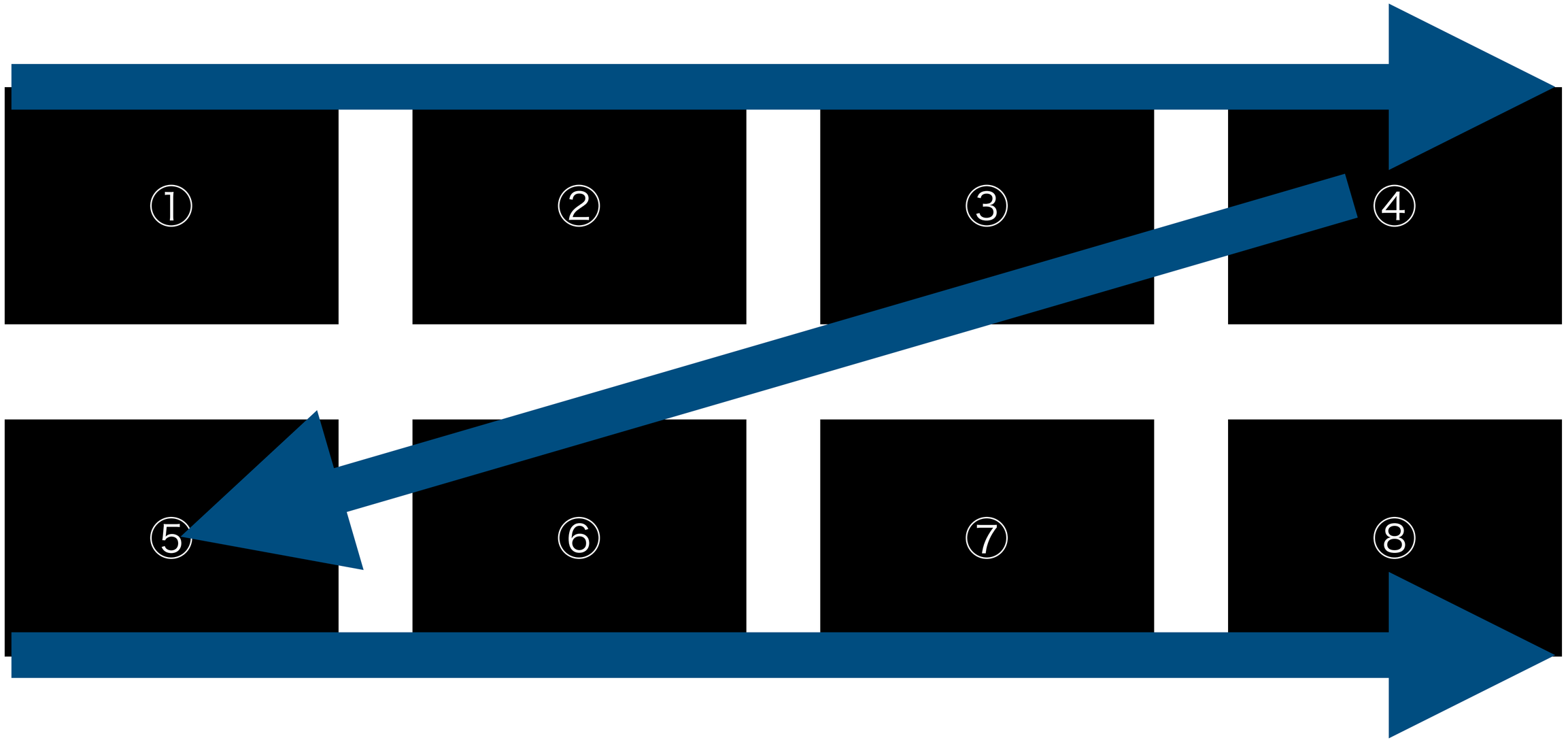


Figure was cited from Elephantech.

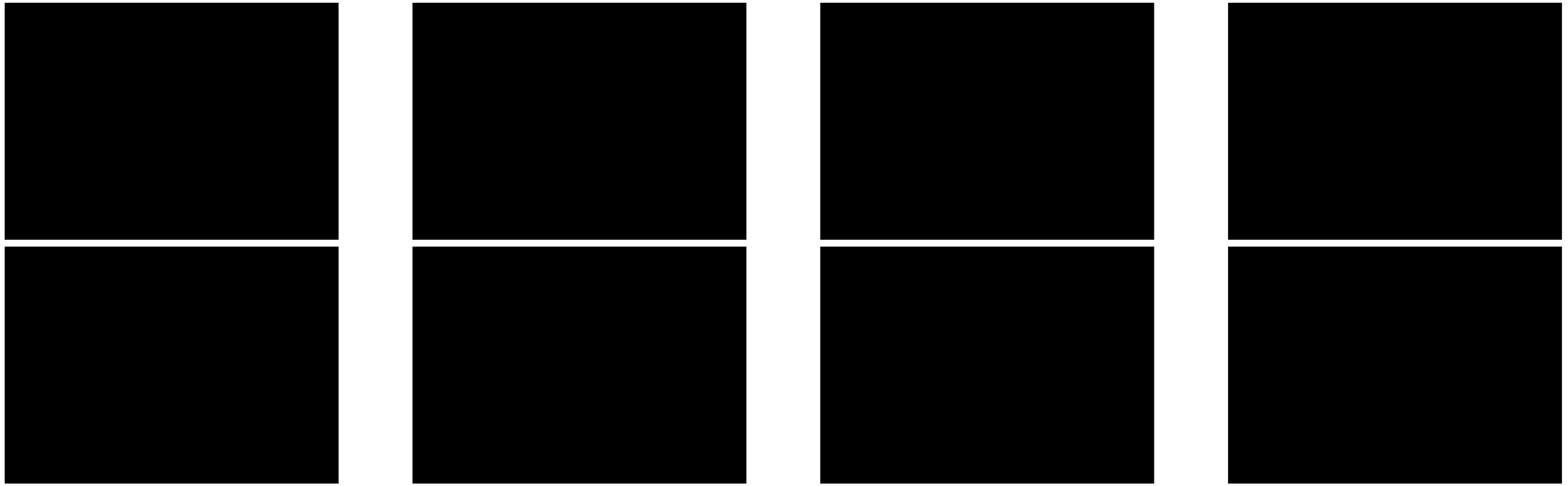
NOTE: Consider Proximity as Well



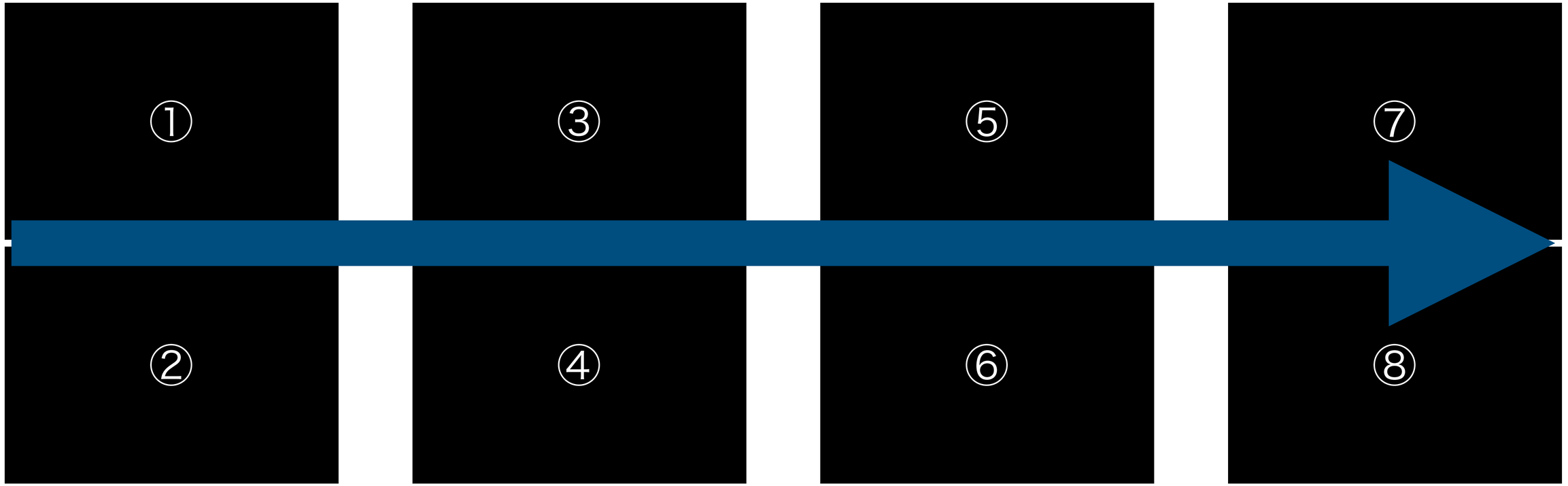
NOTE: Consider Proximity as Well



NOTE: Consider Proximity as Well



NOTE: Consider Proximity as Well



No One Reads Too Many Items

- **Related contents** must be **close**. **Unrelated contents** must be **far.**
- **Invisible lines** should be as **clear and few** as possible.
- **Repeated concepts** improves **consistency.**
- **Meaningful contrasts** are **strong rather than subtle.**
- **Related contents** must be **close**. **Unrelated contents** must be **far.**
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Magical Number 7 (or 3 or others)

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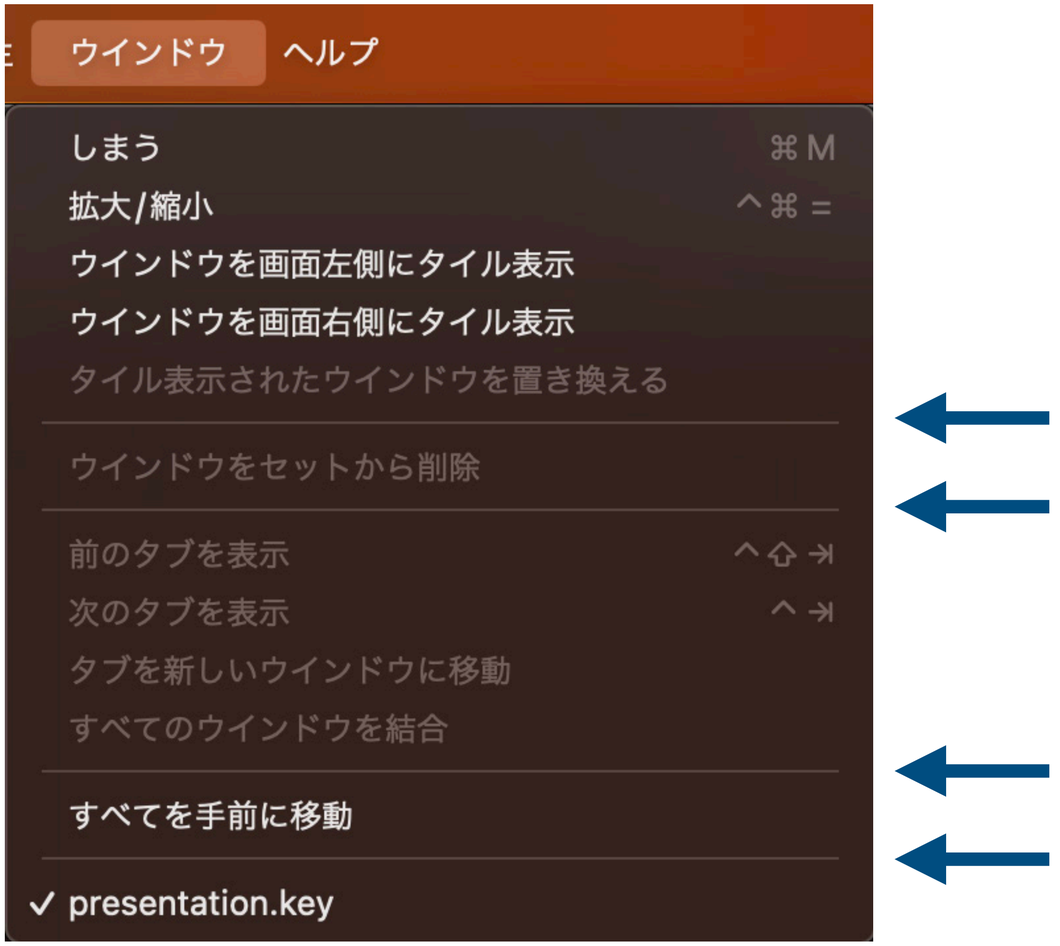
- **Meaningful contrasts** are **strong rather than subtle.**

Group them in a small batch for better readability.

Magical Number 7 (or 3 or others)



Group them in a small batch for better readability.

Four Ideas as **Advances**

Animation

Audience **cannot help** watching animation.

Backgrounds

Effectively use the **meaning of backgrounds.**

Eye Motion

Grasp the **instant eye motion** of audience.

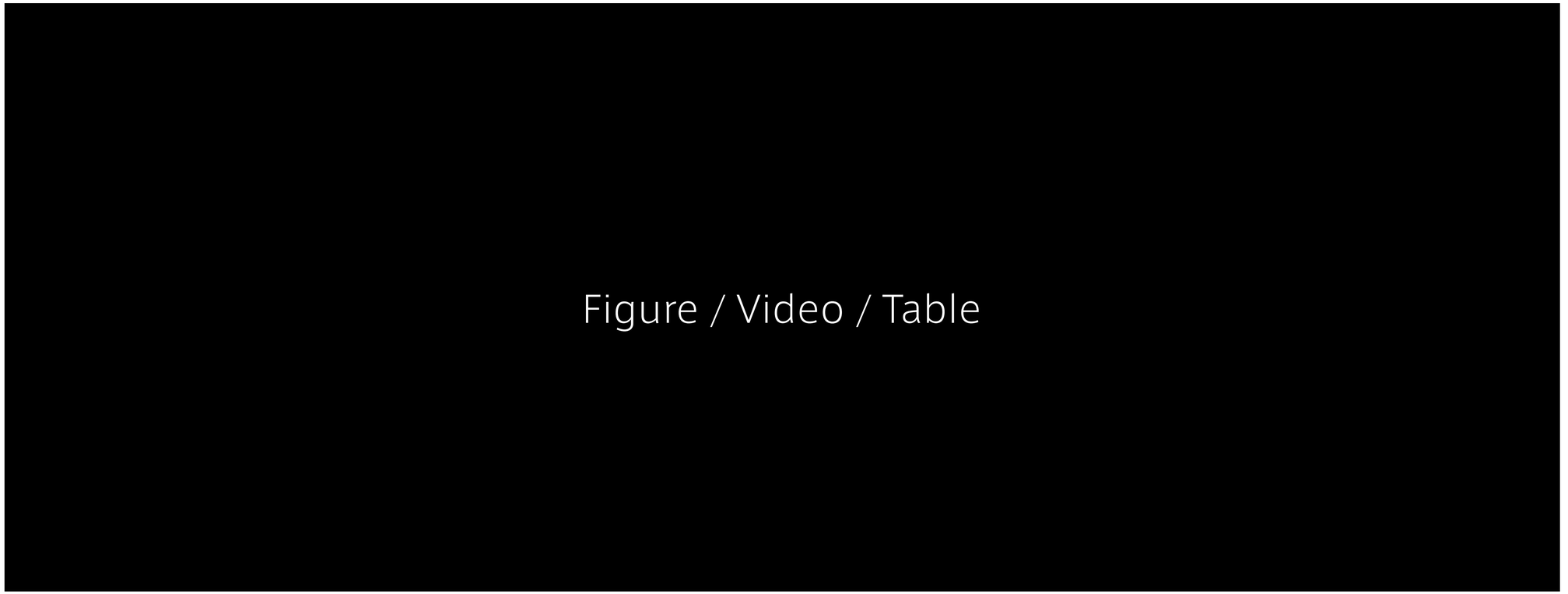
Aspect Ratio

We can actually select **any aspect ratio as curiosity allows**.

ASPECT RATIO

We can actually select any aspect ratio as curiosity allows

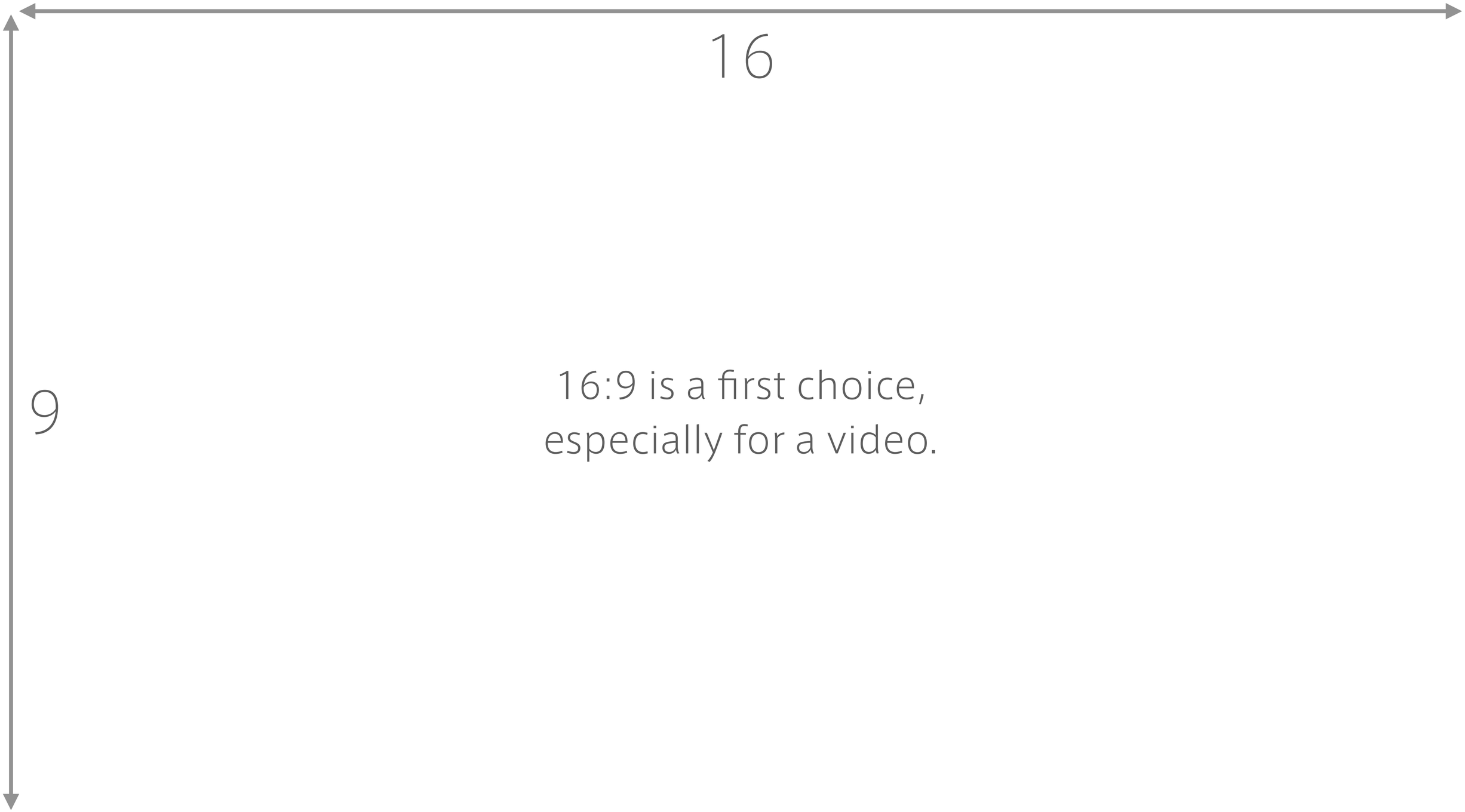
16:9 or 4:3 is the basic aspect ratio



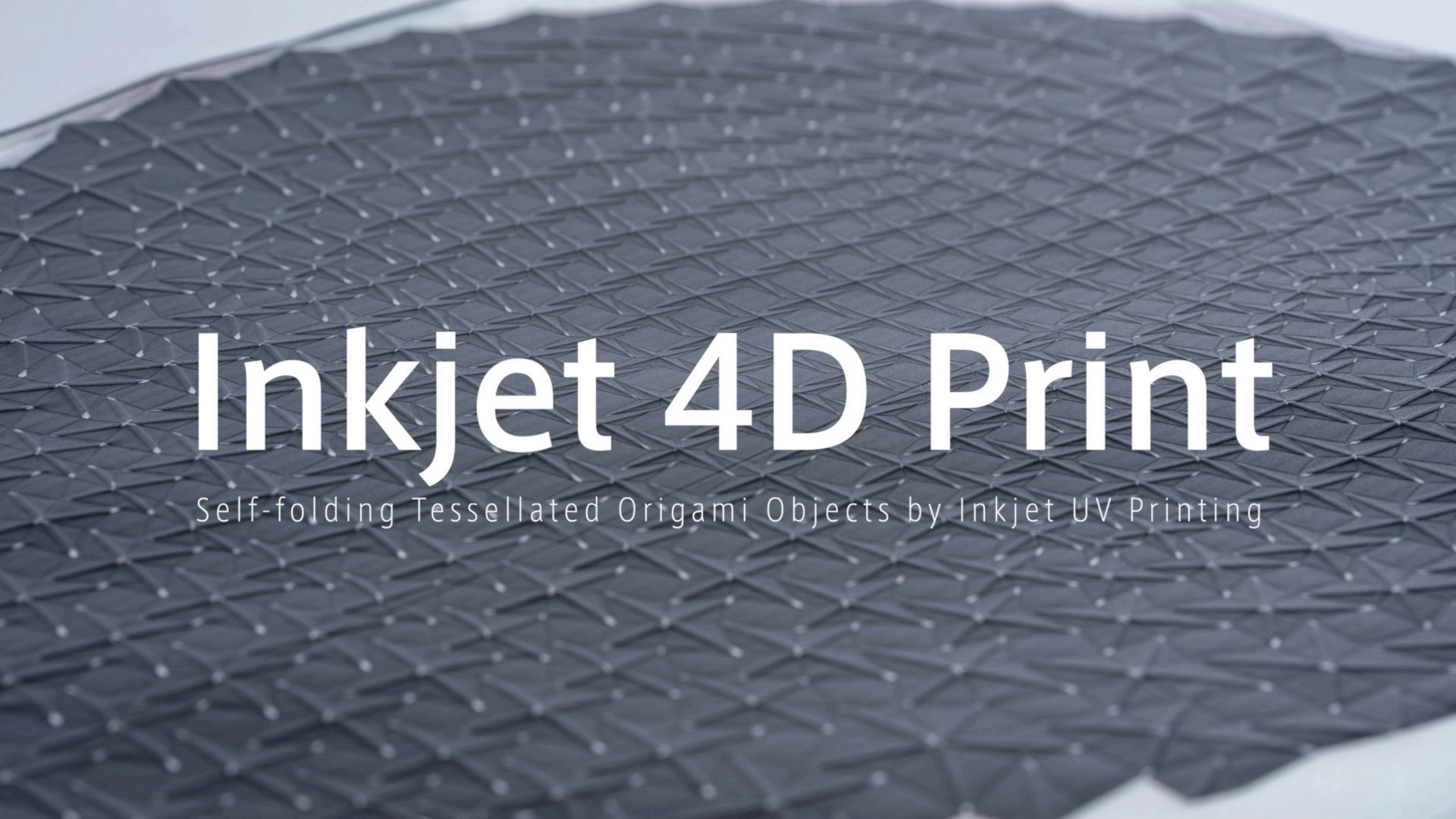
[1]

This slide is made with a 16:9 aspect ratio.

[1] HOGE et al., Reference title, Conference/journal title, 20XX.



16:9 is a first choice,
especially for a video.

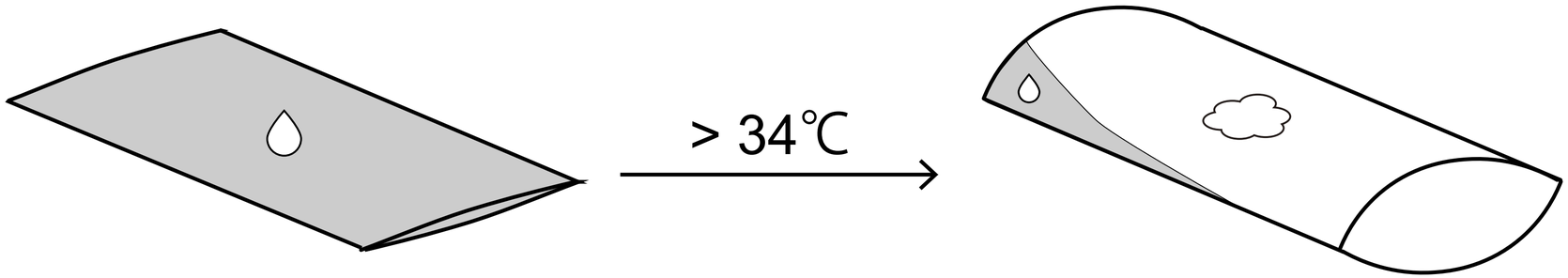


Inkjet 4D Print

Self-folding Tessellated Origami Objects by Inkjet UV Printing

4:3 is also good,
but mainly for an old projector.

A 4:3 slide is like this



Low-boiling-point liquid **NOVEC 7000** evaporates at 34 ℃.
Evaporation makes the pouch inflate and **change its shape.**

Narumi et al., Liquid Pouch Motors, IEEE RA-L 2020.

Intentionally limiting the aspect ratio to 2.35:1 (cinema scope)

Limiting the aspect ratio could lead to **readability**

- **Itemizing ~3 sentences** is sometimes too simple and too “white”
- **Limiting the aspect ratio** could make audience focus on the message
- Extremely speaking, **making them feel comfortable** is enough

Limiting the aspect ratio could lead to **readability**

- **Itemizing ~3 sentences** is sometimes too simple and too “white”
- **Limiting the aspect ratio** could make audience focus on the message
- Extremely speaking, **making them feel comfortable** is enough

The title for the narrow ratio is like this.

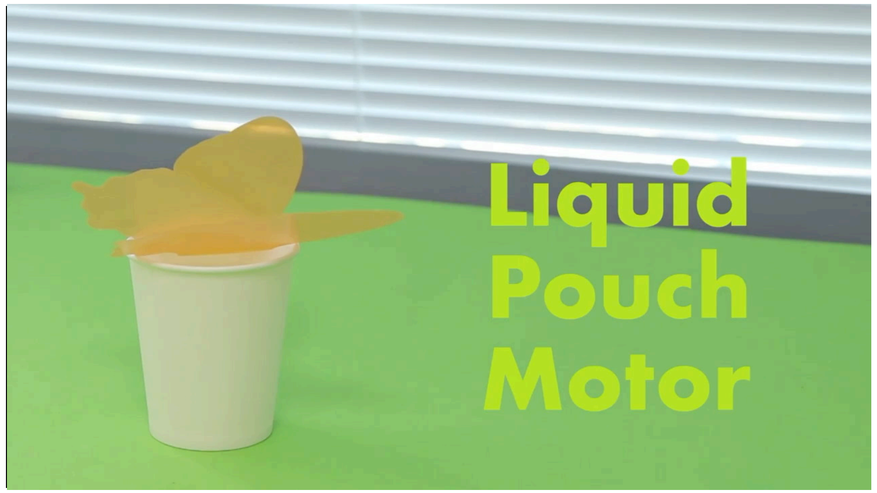
You can continue the long explanation in this place. I saw this presentation format when I was a master course student.

You may think this format is quite useless for academic presentation. But it is useful for, e.g., self-introduction.

Koya Narumi, Ph.D.
Associate Professor,
Keio University

2014 B.Eng. from UTokyo
2017 M.Eng from UTokyo
2020 Ph.D. from UTokyo

Topic: HCI, Digital Fabrication
Hobby: motorcycle riding
Like: wasting money
Goal: saving money



Four Ideas as **Advances**

Animation

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Eye Motion

Grasp the **instant eye motion** of audience.

Aspect Ratio

We can actually select **any aspect ratio as curiosity allows**.

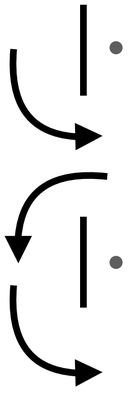
OTHERS

Small topics related to slide design

Regard Audience as **primary school children**

- Even genius professors understand **~30%** of what you mean to say
- **Do NOT tell everything** you know
- Always try to tell just **one message** in one slide

Don’t indent. Find another way



- Indentation seems useful. But it could be harmful.
  - Indentation makes **too many invisible lines**, which is hard to follow.
- Actually, **we do not need to indent at all**.
  - If you think you need indentation, first reduce the amount of messages.

Tradeoff: creativity vs workload

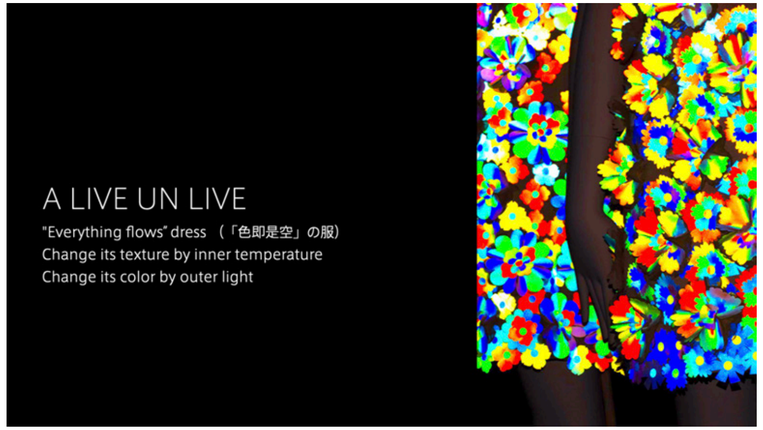
Designing beautiful slides is **NOT** always the answer

Don’t waste time just for lab meetings

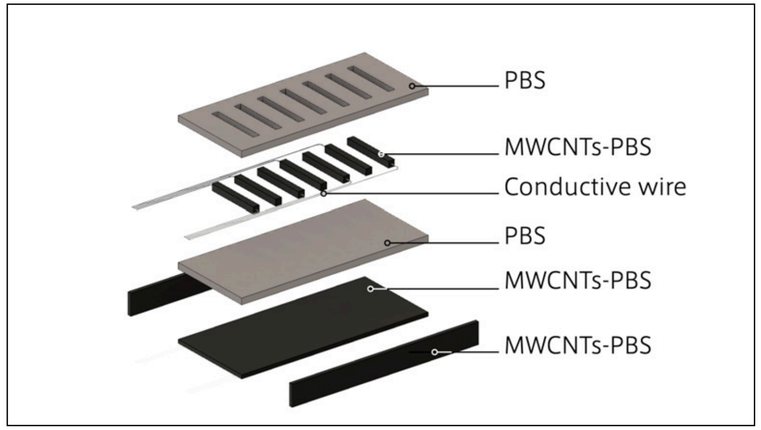
Perhaps **slides are not required** (i.e., use Google Docs or Notion instead)

Conclusion

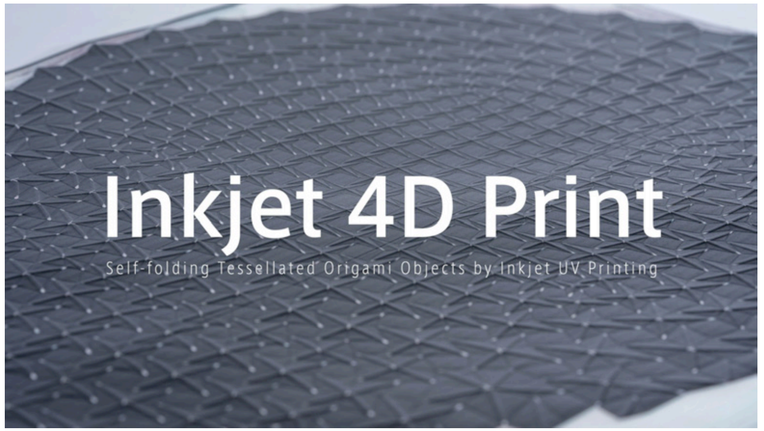
Lets study three presentation methods



Week 3: **Slides**



Week5: **Figures**



Week6: **Videos**

Four Design Principles as **Basics**

Proximity

Related contents must be **close**. **Unrelated contents** must be **far.**

Alignment

Invisible lines should be as **clear and few** as possible.

Repetition

Repeated concepts improves **consistency.**

Contrast

Meaningful contrasts are **strong rather than subtle.**

Concepts are cited from "The Non-Designer's Design Book"

Four Ideas as **Advances**

Animation

Audience **cannot help** watching animation.

Backgrounds

Effectively use the **meaning of backgrounds.**

Eye Motion

Grasp the **instant eye motion** of audience.

Aspect Ratio

We can actually select **any aspect ratio as curiosity allows**.

Example Slides I made in the past

SELF-INTRODUCTION

自己紹介

略歴

鳴海 紘也（なるみ こうや | Koya Narumi）

2013	東京大学 文科 I 類 修了
2015	東京大学 工学部 電子情報工学科 卒業
2017	東京大学 大学院工学系研究科 電気系工学専攻 修士課程 修了
2017	日本学術振興会特別研究員（DC1）
2018	Carnegie Mellon University HCII Research Scholar（〜2019年04月）
2018	JSPS ACT-I「情報と未来」個人研究者
2020	東京大学 大学院情報理工学系研究科 電子情報学専攻 博士課程 修了
2020	東京大学 大学院情報学環 先端表現情報学コース 助教
2021	**東京大学 大学院工学系研究科 電気系工学専攻 特任講師**

専門分野

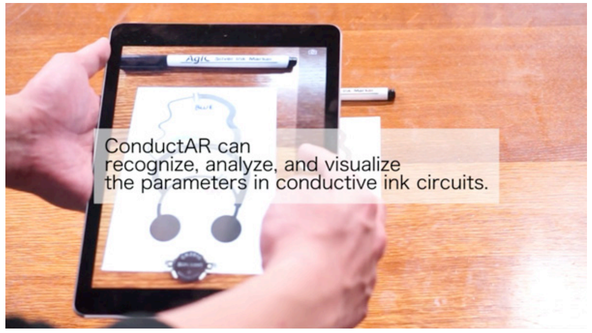
大分類：　ヒューマンコンピュータインタラクション (HCI)

小分類：　**コンピュテーショナル・ファブリケーション**
マテリアル・インタラクション
ソフト・ロボティクス

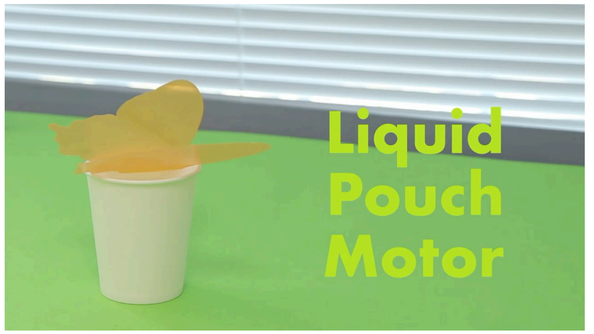
概要：　特殊な**素材**と**構造**を計算により配置することで、衣服・プロダクト・食品・乗り物など人間の生活領域に存在する「モノ」を**設計**する。その後、インクジェットプリンタ・3Dプリンタ・CNCなどのデジタルファブリケーションツールによりそれらを実際に**製造**し、人間の新たな体験を創出する。

趣味：バイク

Circuit Eraser
ACM CHI EA 2015, Kickstarter



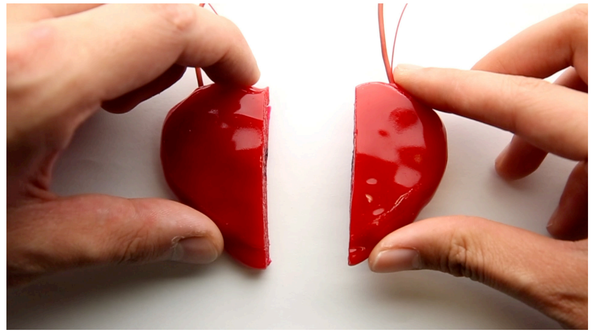
ConductAR
ACM UbiComp 2016



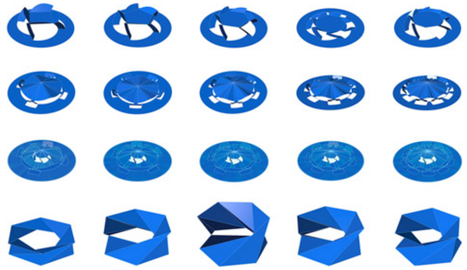
Liquid Pouch motors
IEEE ICRA 2017, IEEE RA-L 2020

Papilion
Ars Electronica 2017

A LIVE UN LIVE
六本木クロッシング 2018



Self-healing UI
ACM UIST 2019

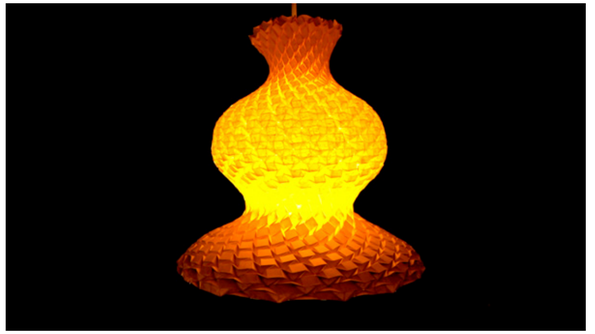


Kirigami Haptic Swatches
ACM CHI 2020

Pop-up Print
ACM UIST 2020

poimo
ACM UIST 2020

Flower Jelly Printer
ACM CHI 2021



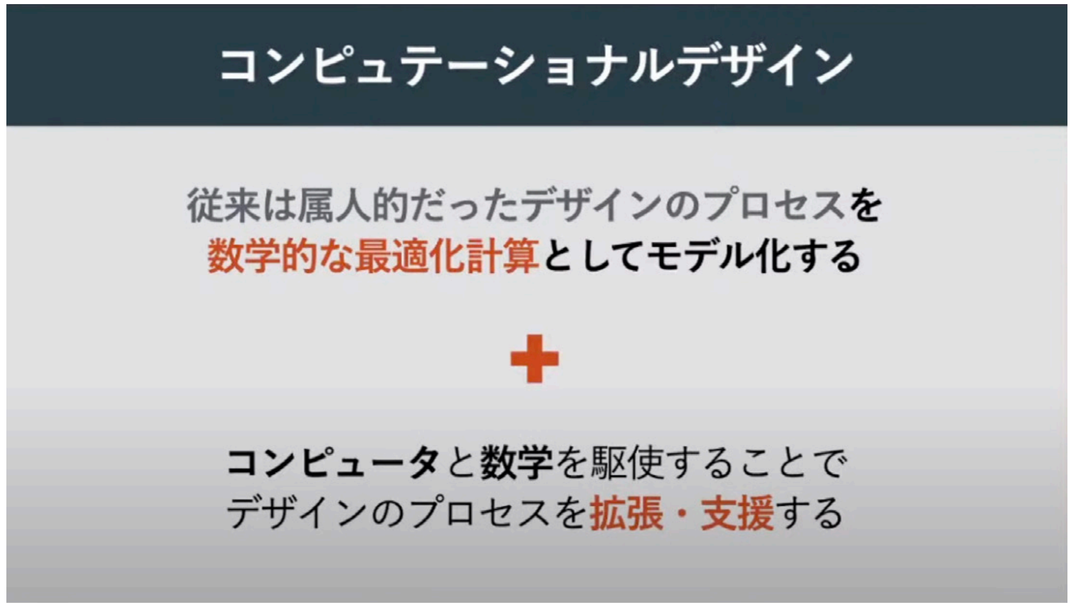
Crane
ACM TOCHI (CHI) 2023

Inkjet 4D Print
ACM TOG (SIGGRAPH) 2023

Introduction: Computational Fabrication & Material Interaction

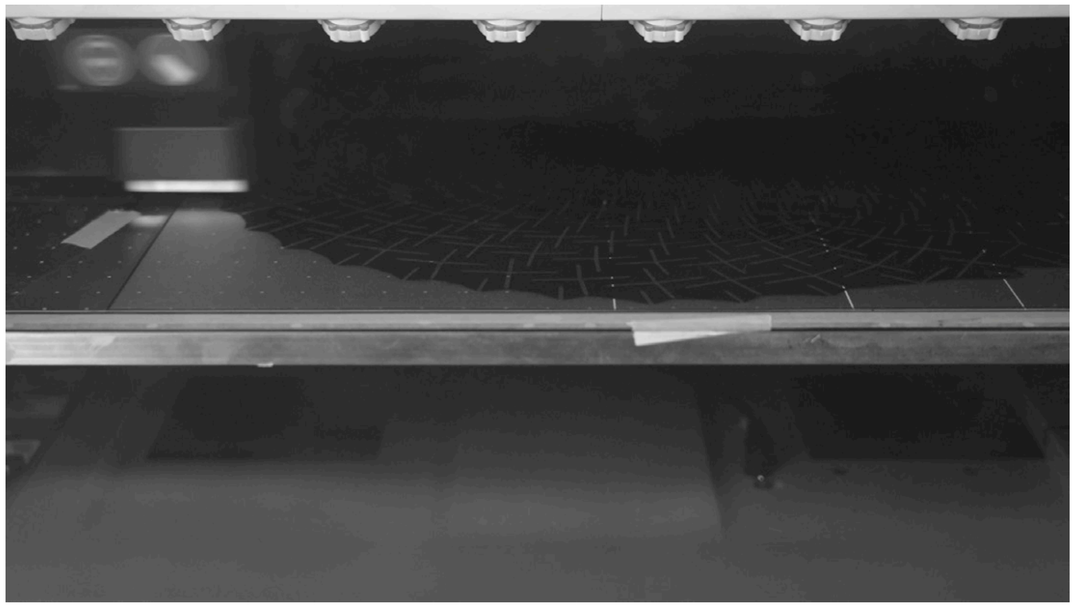
計算製造とマテリアル・インタラクション

計算製造 (Computational Fabrication) とは



Computational Design [1]

＋



Digital Fabrication

最近の造語（2010s~）なので広く共通の定義はないが、

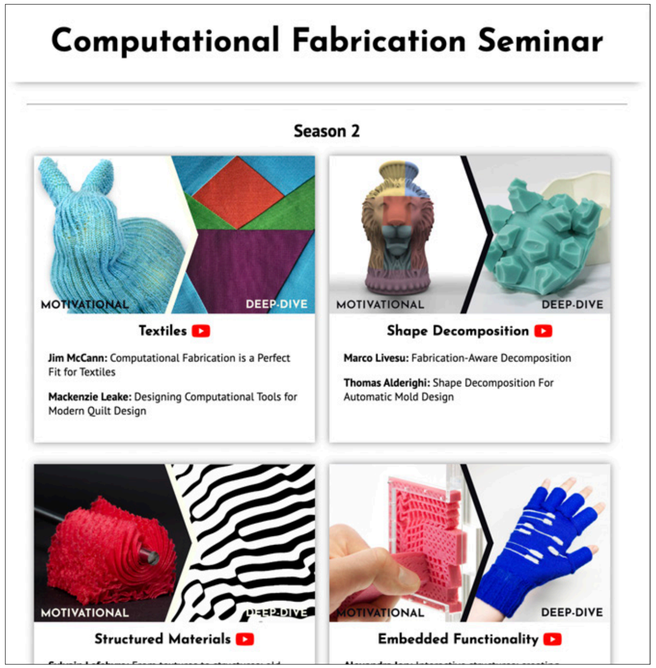
現実のツールで作れる素材と構造の中で、計算設計した構造物を作ること。逆にそれを作れる装置自体を作ること

---

[1] 小山裕己さんの発表スライドから引用 (https://youtu.be/_Q4QJO8SEsY)

計算製造 (Computational Fabrication) の参考資料

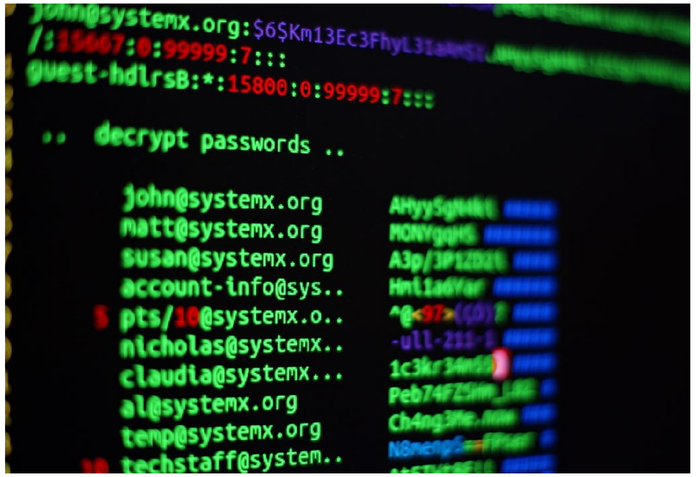
コンピュテーショナル・ファブリケーション
2020
田中浩也 & 舘知宏
彰国社



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

デジタルファブリケーションとメディア
2024.4予定
三谷純・田中浩也・小山裕己・筧康明・五十嵐悠紀
コロナ社

マテリアル・インタラクションとは①



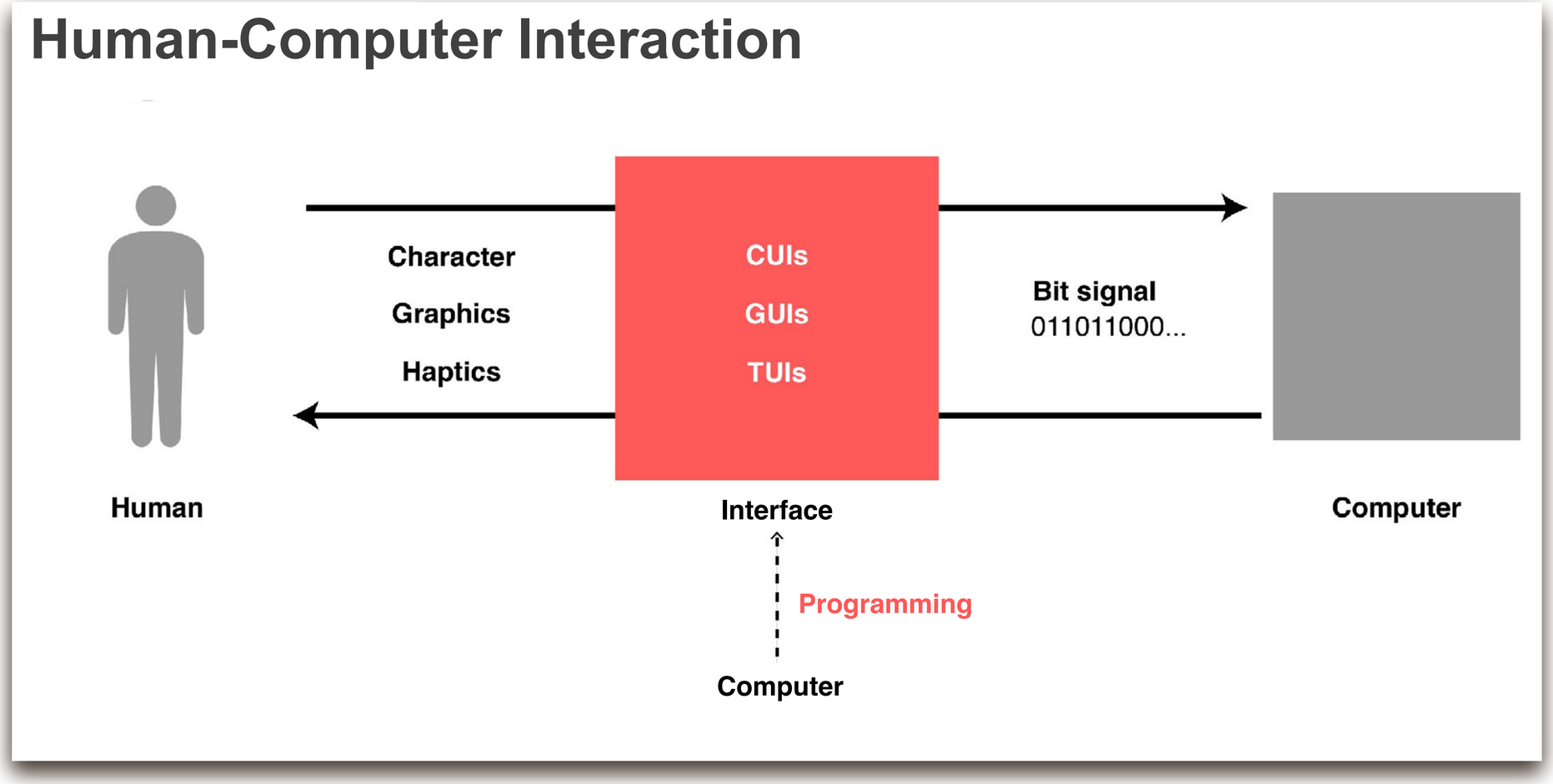
Character User Interfaces
言語

Graphical User Interfaces
2D形状

Touch Interfaces
触覚

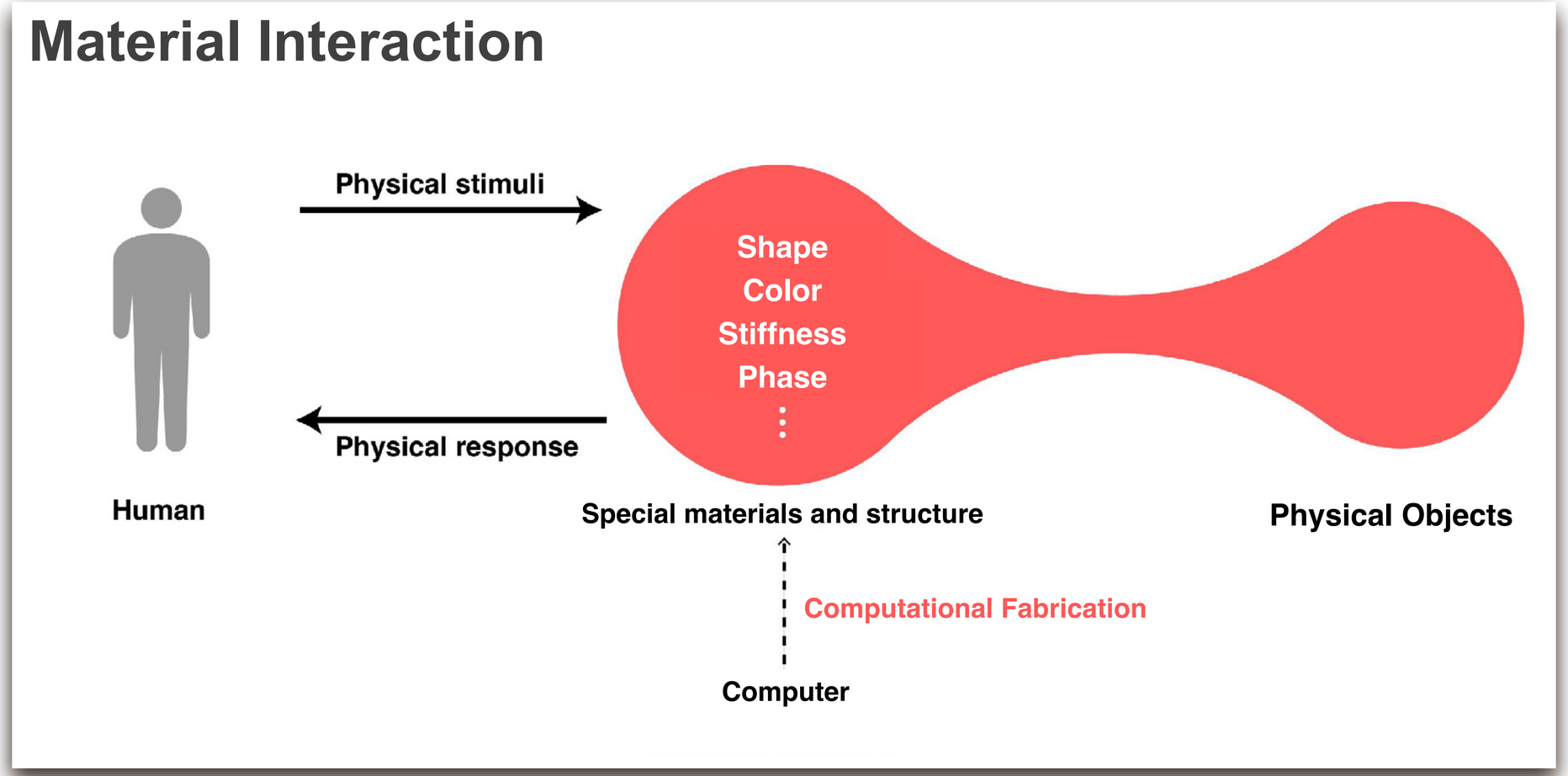
従来のインタラクションの歴史は、人間機と計算機を仲介する**インタフェース（翻訳機）**の歴史

マテリアル・インタラクションとは②



従来のインタラクションの歴史は、人間機と計算機を仲介する**インタフェース（翻訳機）**の歴史

マテリアル・インタラクションとは③



マテリアル・インタラクションとは、計算機に必ずしも頼らずに
モノの特殊な素材や構造を直接利用したインタラクションを実現すること

コンピュテーショナル・ファブリケーション：計算して特殊な素材と構造を持つモノを作る。モノを作れる装置を作る

×

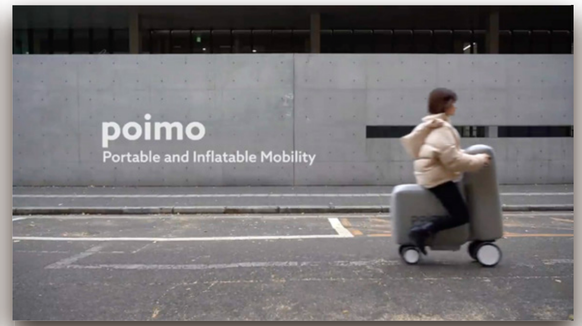
マテリアル・インタラクション：特殊な素材と構造で新たな体験を生み出す

Our Projects

これまでのプロジェクト

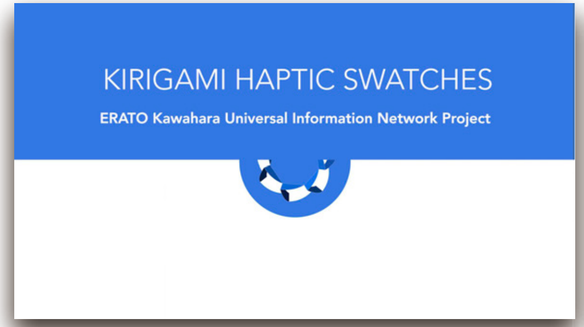
Liquid Pouch Motors
ICRA2017 + RoboSoft2020

Self-healing UI
UIST2019



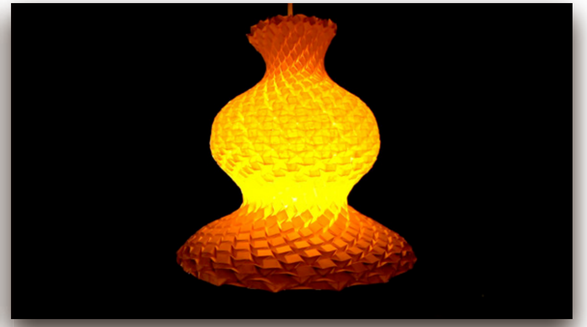
poimo
CHI EA 2020 & UIST2020

Pop-up Print
UIST2020



Kirigami Haptic Swatches
CHI2020

Flower Jelly Printer
CHI2021



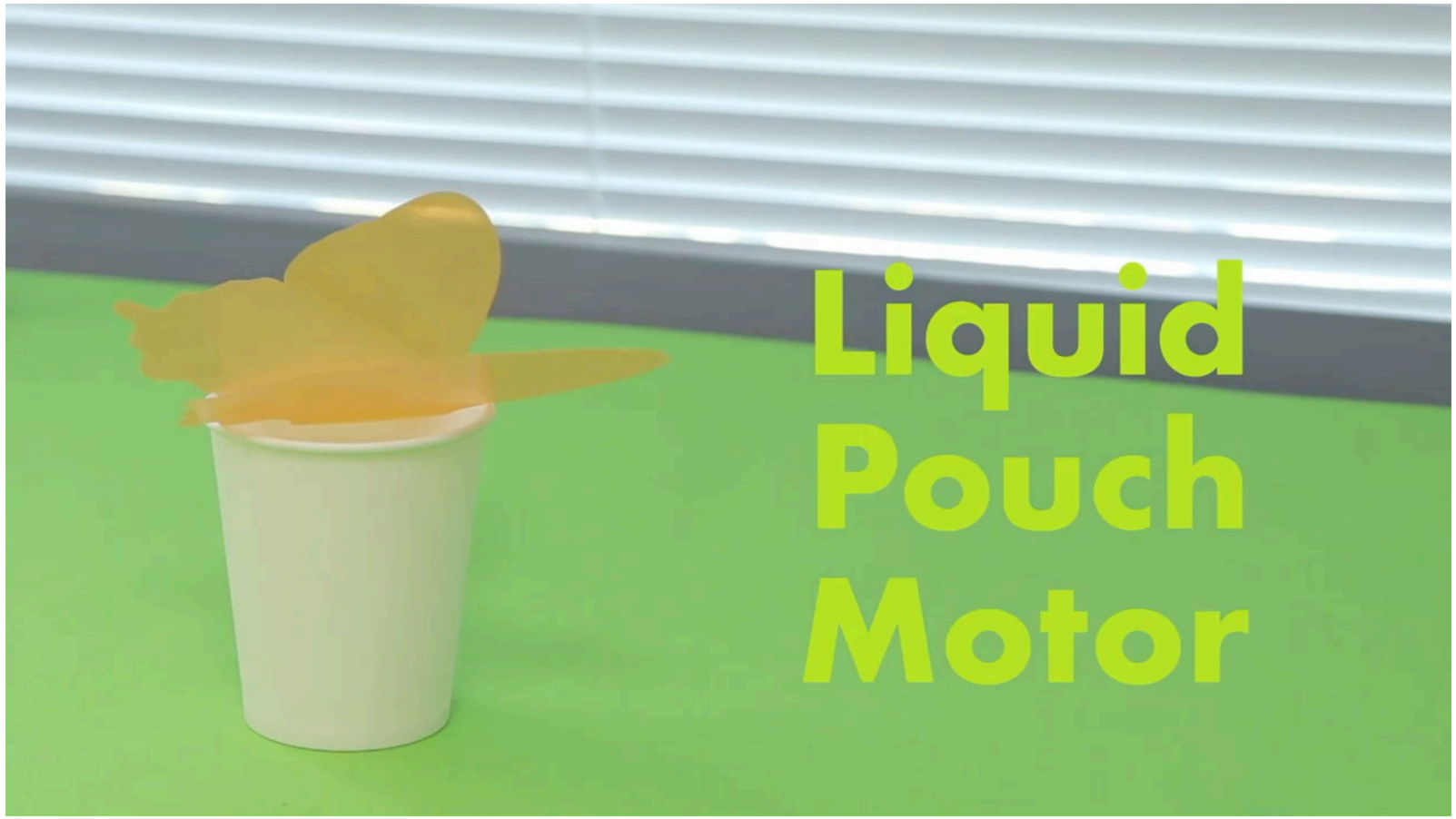
Crane
TOCHI (CHI2023)

Inkjet 4D Print
TOG (SIGGRAPH2023)

Liquid Pouch Motors

Thin, Lightweight, Flexible Actuators for Paper Interface

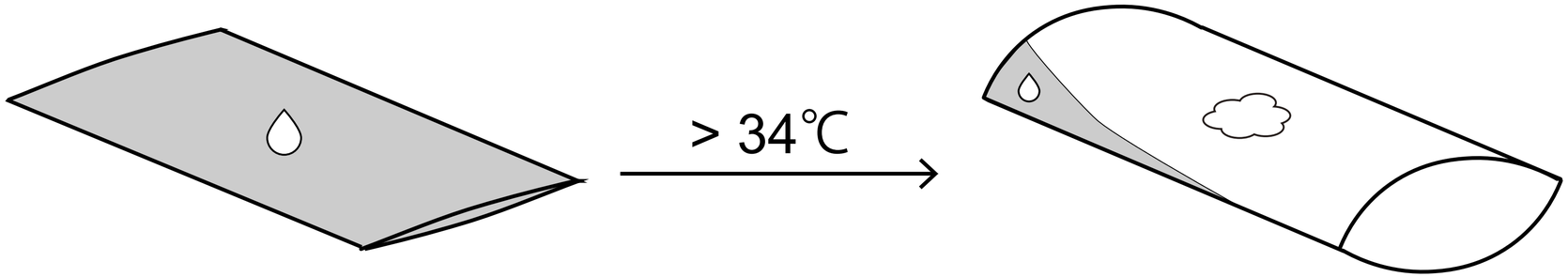
Liquid Pouch Motors



[1]

[1] http://opensoftmachines.com

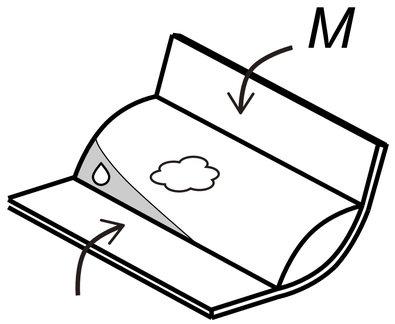
原理

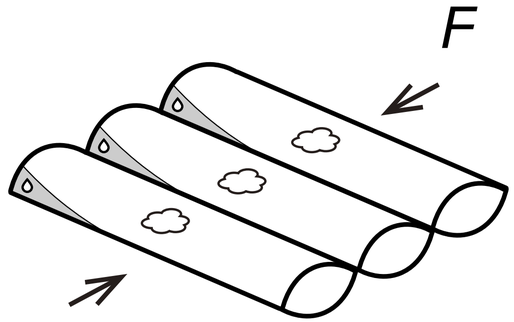


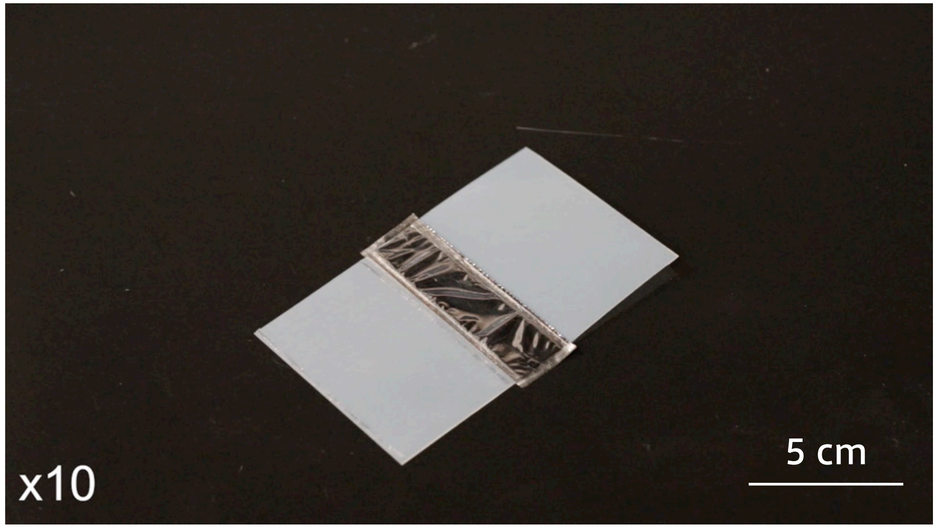
パウチの内部には**34 ℃で沸騰する低沸点液体**「Novec7000」が封入されている
加熱することにより液体が気化し、形状が変化する

Narumi, Sato, Nakahara, Seong, Morinaga, Kakehi, Niiyama & Kawahara, Liquid Pouch Motors, IEEE RA-L 2020.

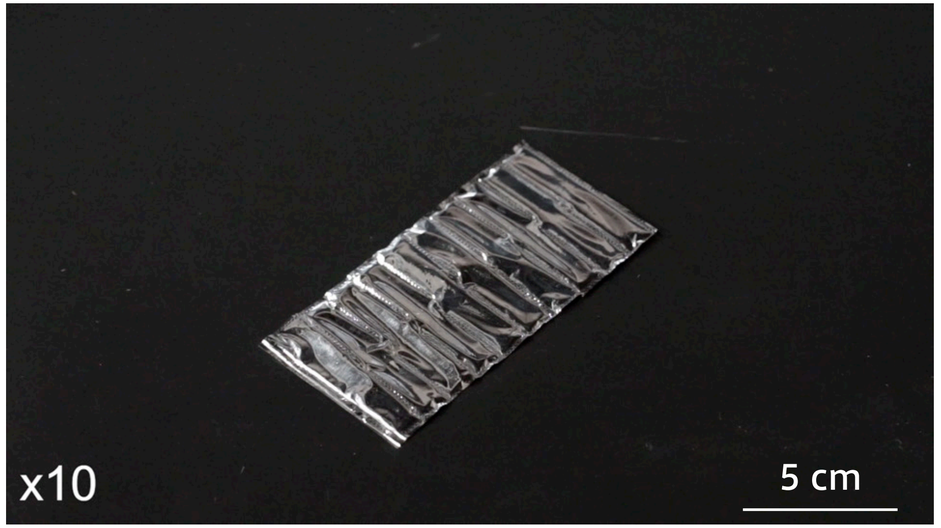
動作モード







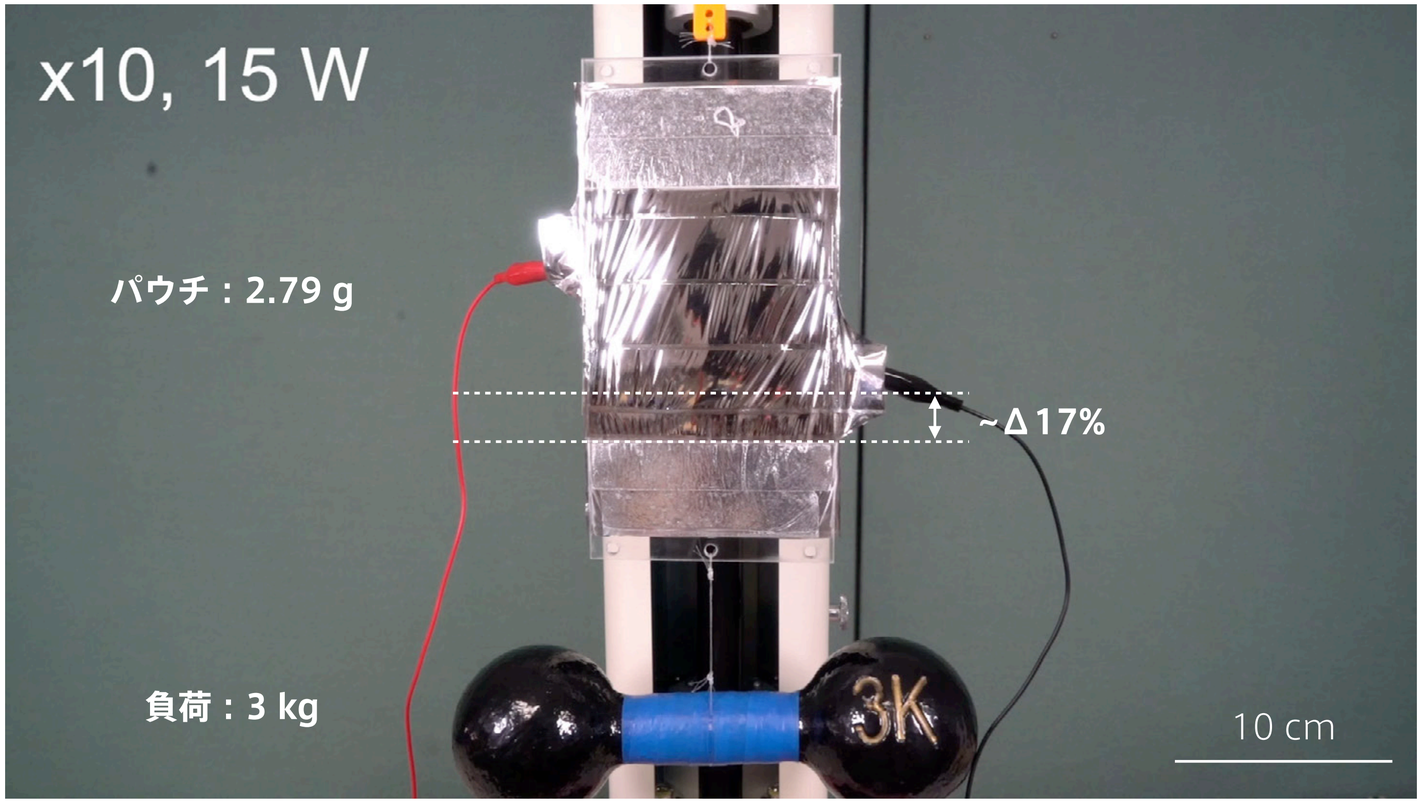
Angular motion



Linear motion

Narumi, Sato, Nakahara, Seong, Morinaga, Kakehi, Niiyama & Kawahara, Liquid Pouch Motors, IEEE RA-L 2020.

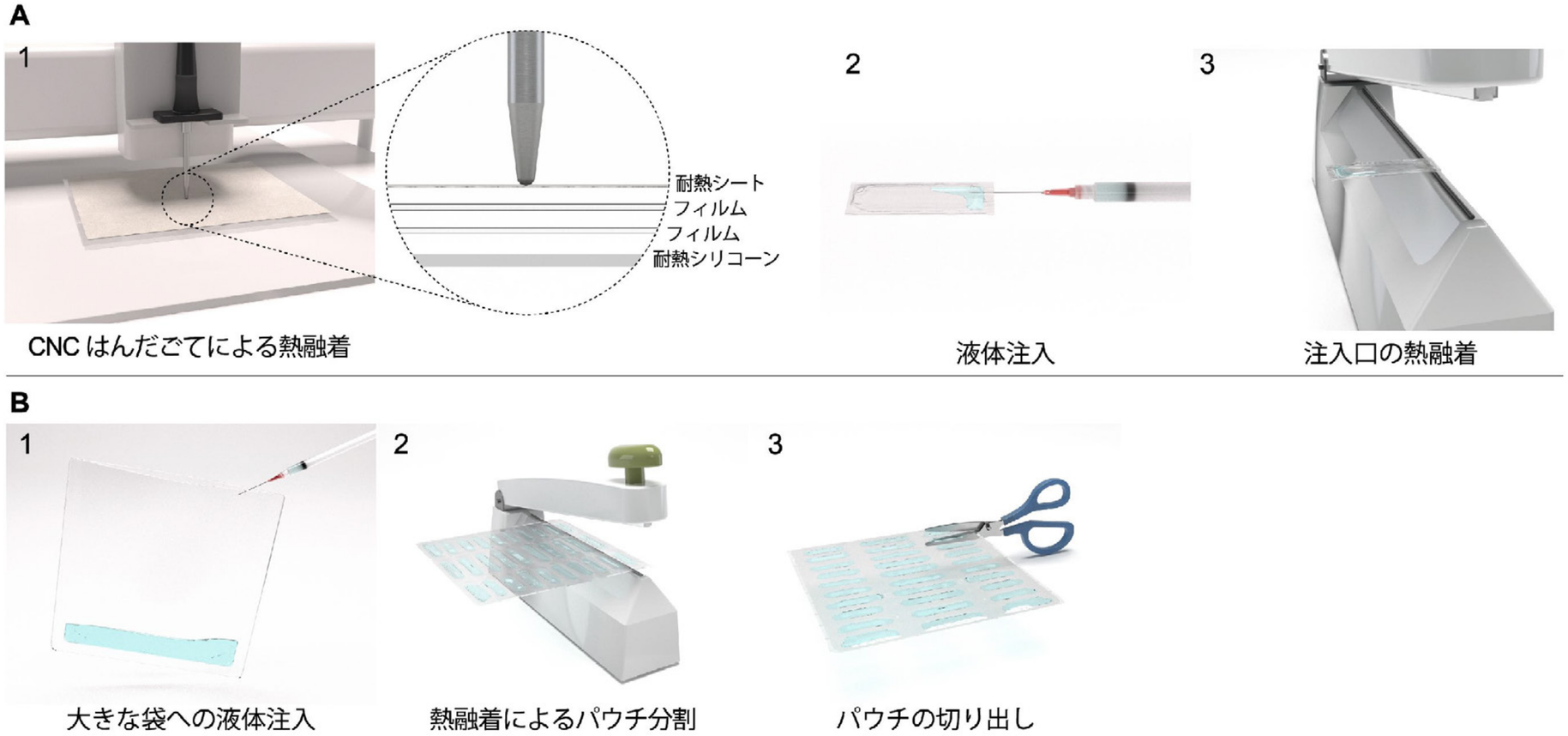
高い質量-負荷比



空気圧アクチュエータの重いチューブやポンプがないため、**自重の1000倍以上の負荷を持ち上げられる**

Narumi, Sato, Nakahara, Seong, Morinaga, Kakehi, Niiyama & Kawahara, Liquid Pouch Motors, IEEE RA-L 2020.

ファブリケーション



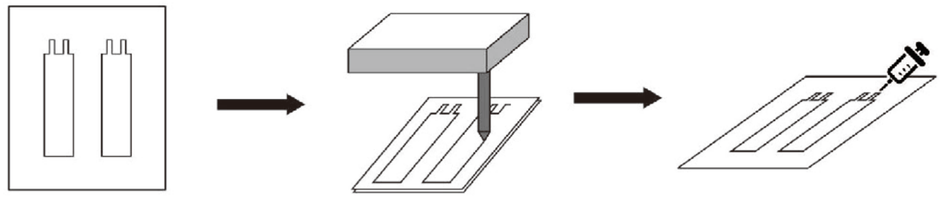
試作をする場合は、CNC制御のはんだごてにより自由な平面形状を作製可能
大量生産の場合は、流れ作業の熱融着が可能

Narumi, Sato, Nakahara, Seong, Morinaga, Kakehi, Niiyama & Kawahara, Liquid Pouch Motors, IEEE RA-L 2020.

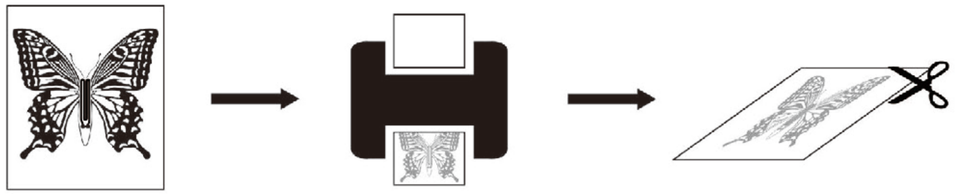
Applications

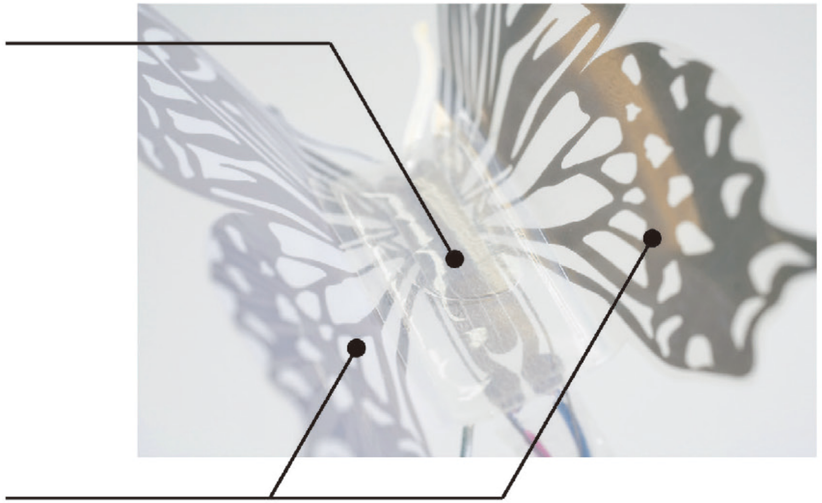
印刷できるロボット・インタフェース

低沸点液体を封入した
モーターの作製



電熱線を含む
銀ナノインク回路の作製

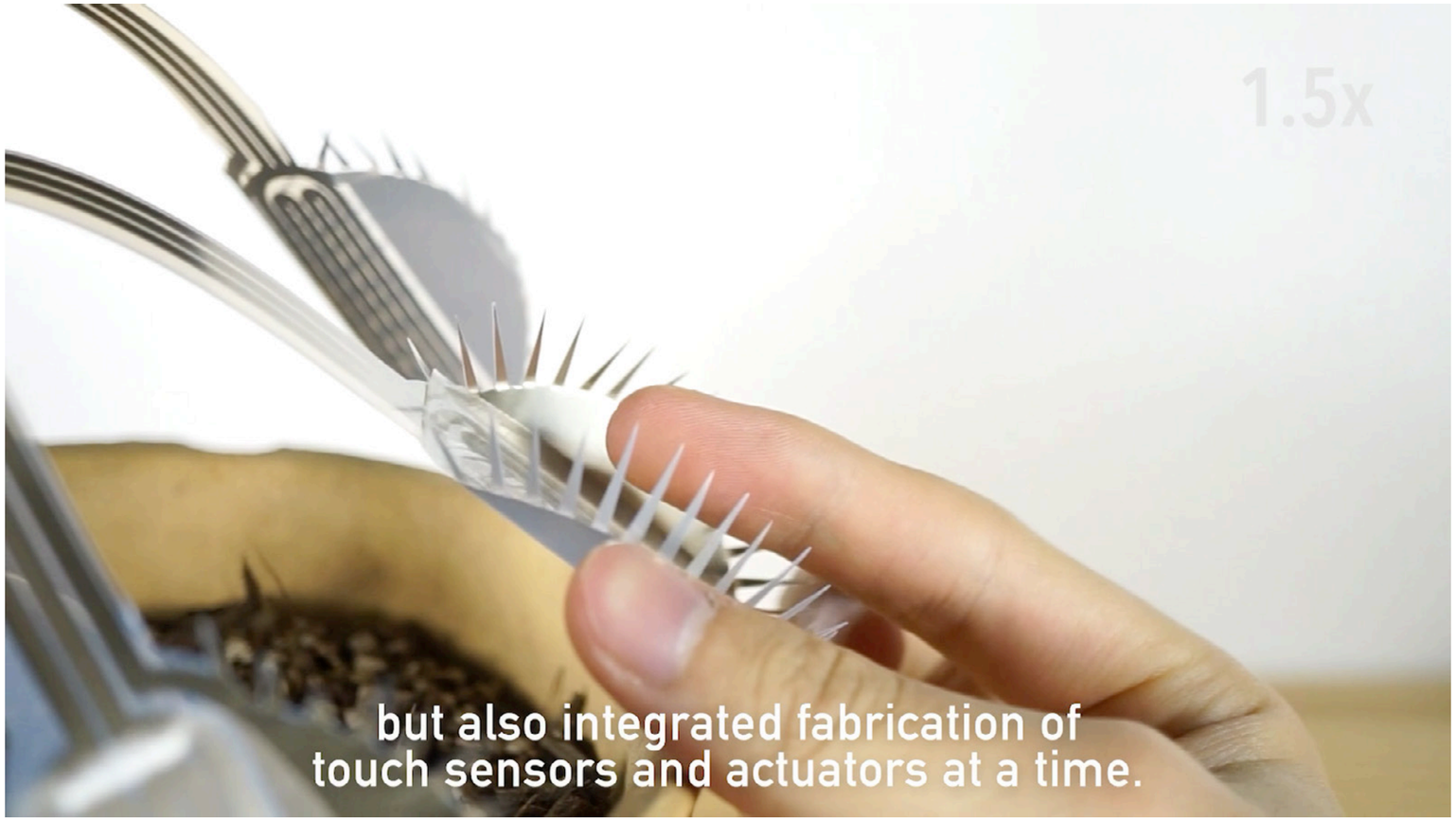




モータの印刷 + 電熱線/配線/センサなどの回路素子の印刷 により**印刷できるロボット**を実現

Nakahara, Narumi, Niiyama, & Kawahara, Electric Phase-change Actuator, ICRA2017.

ハエトリソウ型インタフェース



モータ・電熱線・タッチセンサ・配線が2回の印刷で搭載されたインタフェース

Nakahara, Narumi, Niiyama, & Kawahara, Electric Phase-change Actuator, ICRA2017.

Papilionのコンセプト

Liquid Pouch Motorは**無電源**で駆動しても良いのではないか？
知的な壁紙として利用できないか？

↓

Pavilion <パビリオン> + Papillon <蝶> = Papilion

環境熱で動作する壁紙

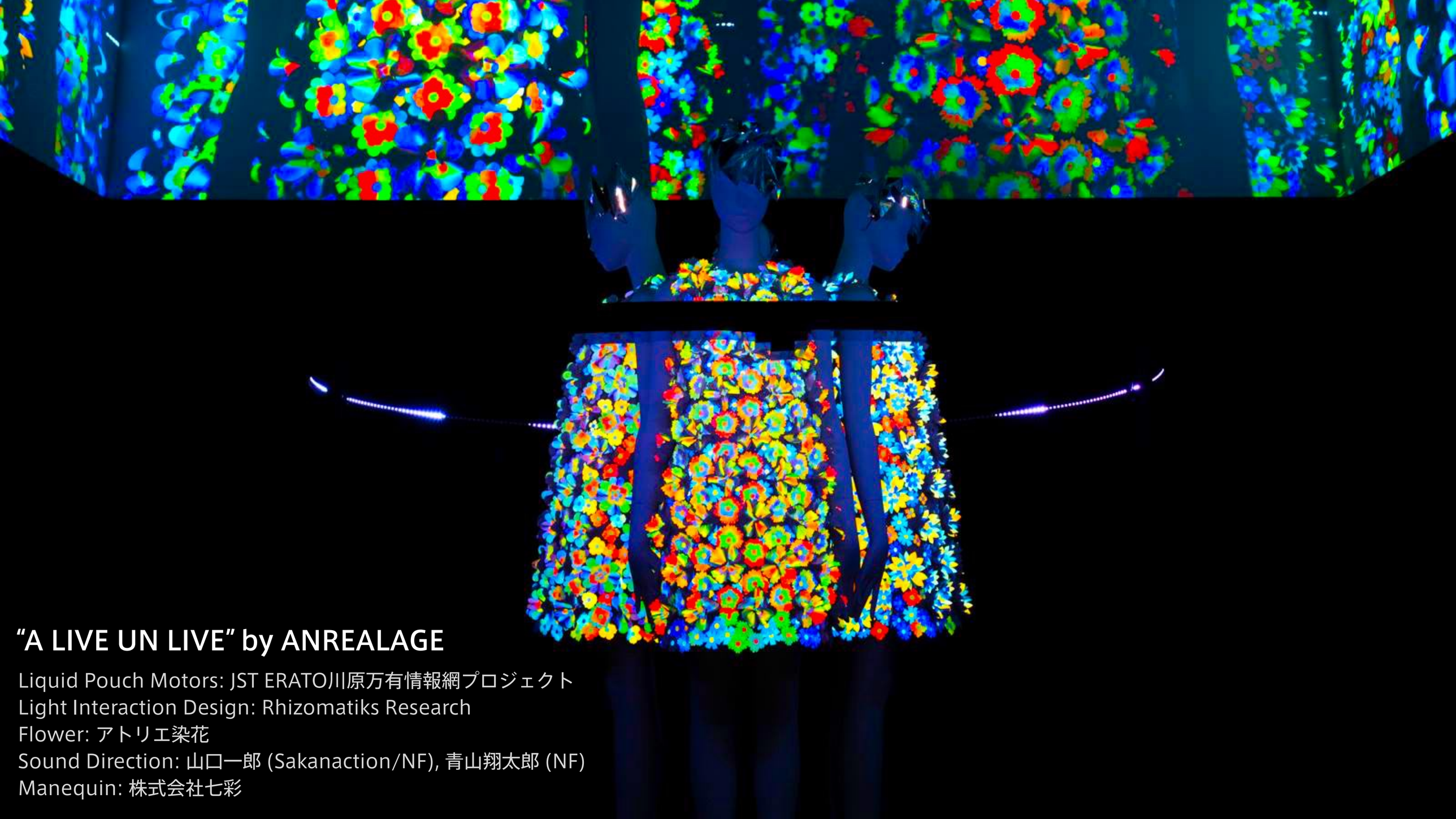
熱いときには窓を空け、寒いときには窓を閉める

環境の熱と光により**無電源で動作**する

完全に**無線で動作**する

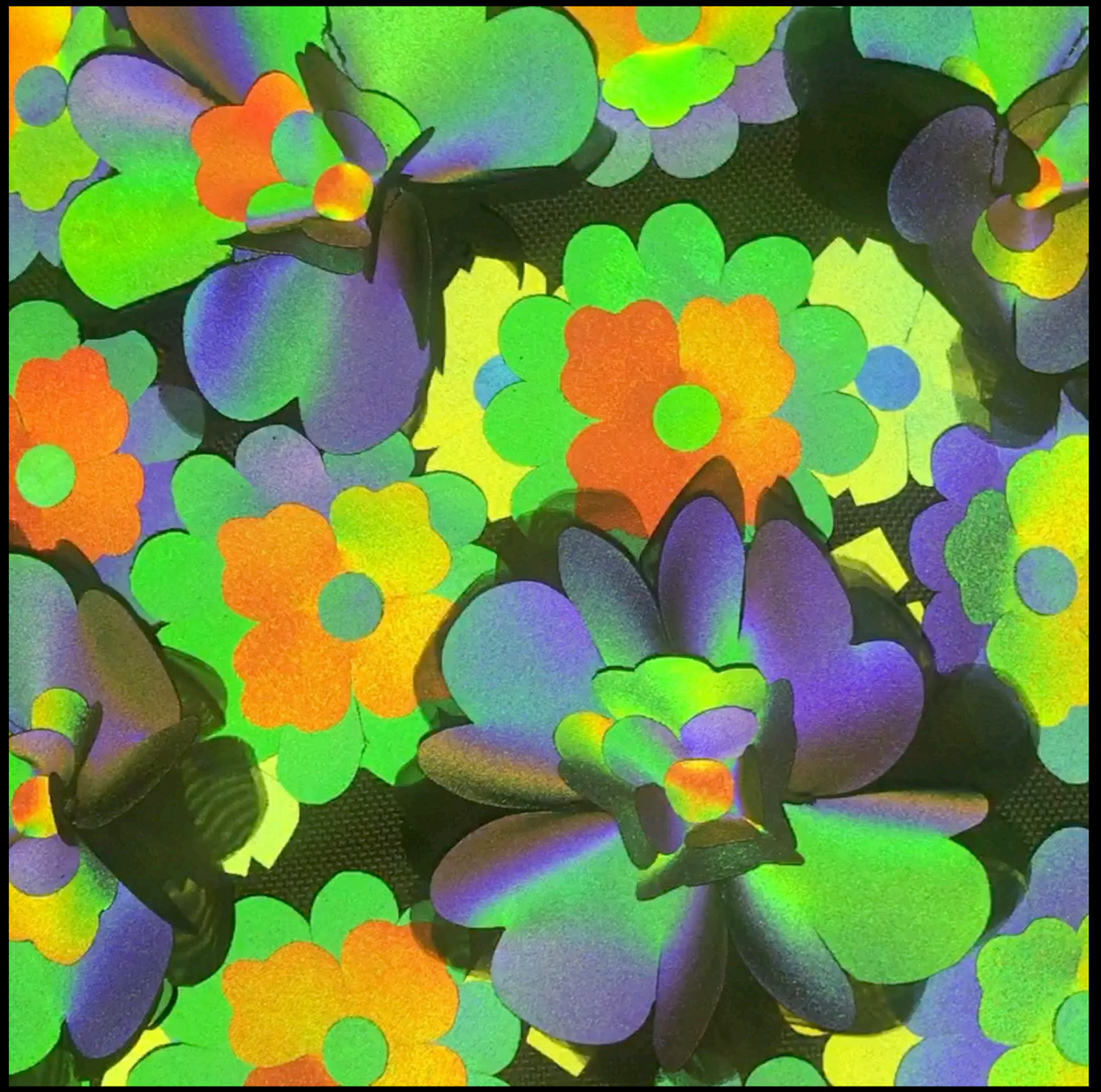
取り替え可能・大量生産可能・透過率の選択可能

Sato, Nakahara, Narumi, Kakehi, Niiyama, & Kawahara, Papilion, Ars Electronica 2017.

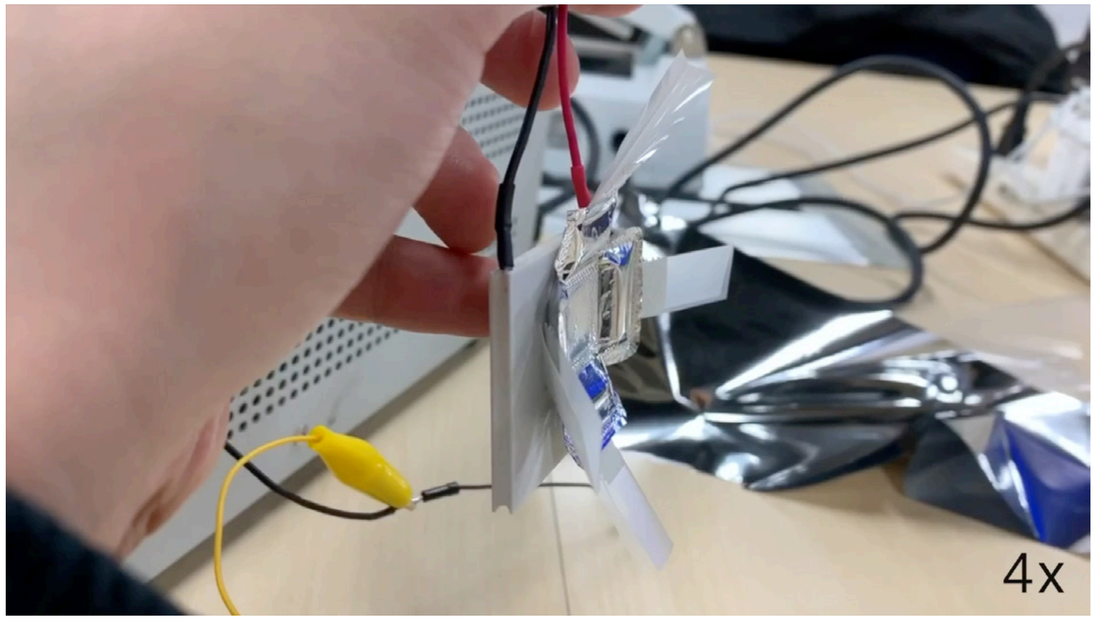


“A LIVE UN LIVE” by ANREALAGE

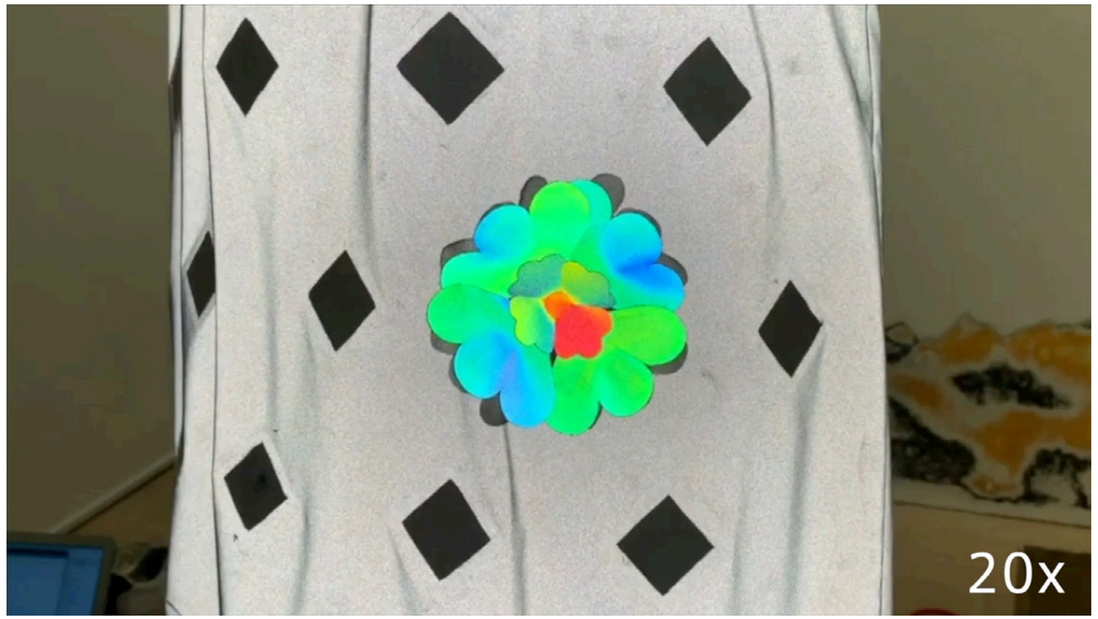
Liquid Pouch Motors: JST ERATO川原万有情報網プロジェクト
Light Interaction Design: Rhizomatiks Research
Flower: アトリエ染花
Sound Direction: 山口一郎 (Sakanaction/NF), 青山翔太郎 (NF)
Manequin: 株式会社七彩



コサージュの背後にLiquid Pouch Motorsを配置



ペルチェ素子により体温を再現



コサージュをLiquid Pouch Motorsが駆動

ANREALAGE, A LIVE UN LIVE, 六本木クロッシング, 2019.

A LIVE UN LIVE

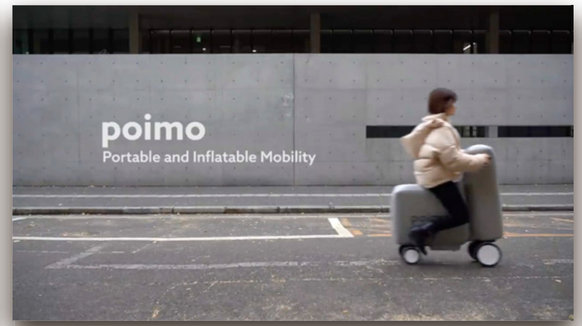
"Everything flows" dress （「色即是空」の服）

Change its texture by inner temperature

Change its color by outer light

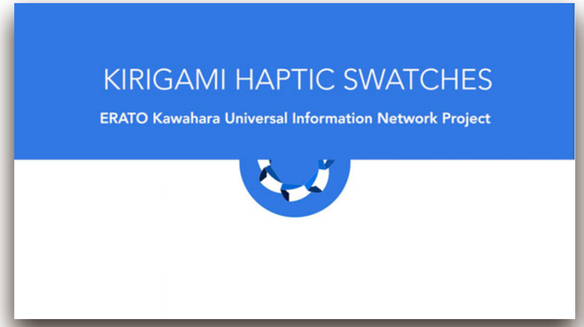
Liquid Pouch Motors
ICRA2017 + RoboSoft2020

Self-healing UI
UIST2019



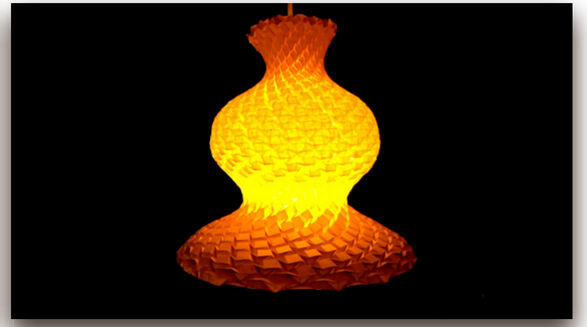
poimo
CHI EA 2020 & UIST2020

Pop-up Print
UIST2020



Kirigami Haptic Swatches
CHI2020

Flower Jelly Printer
CHI2021



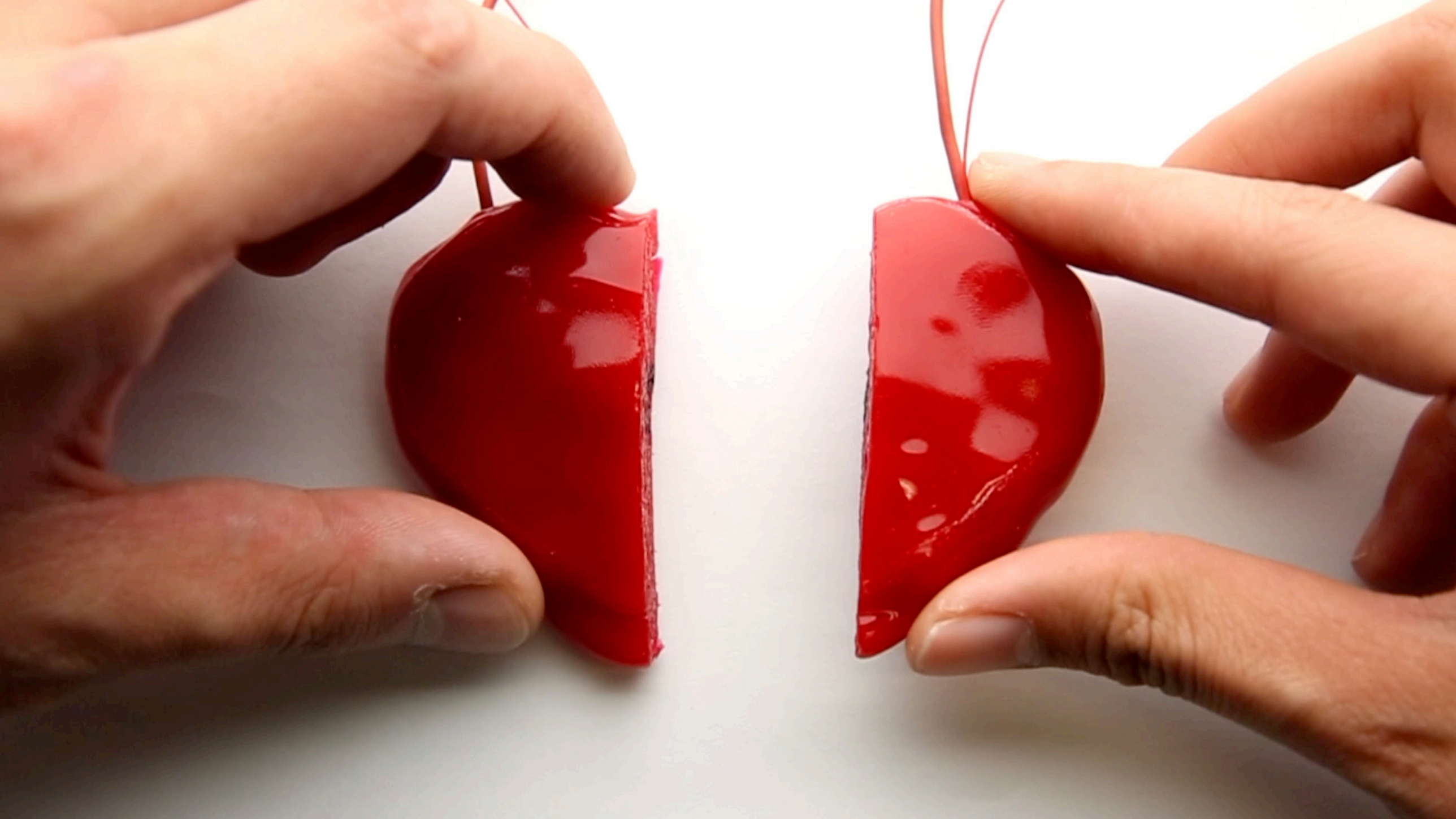
Crane
TOCHI (CHI2023)

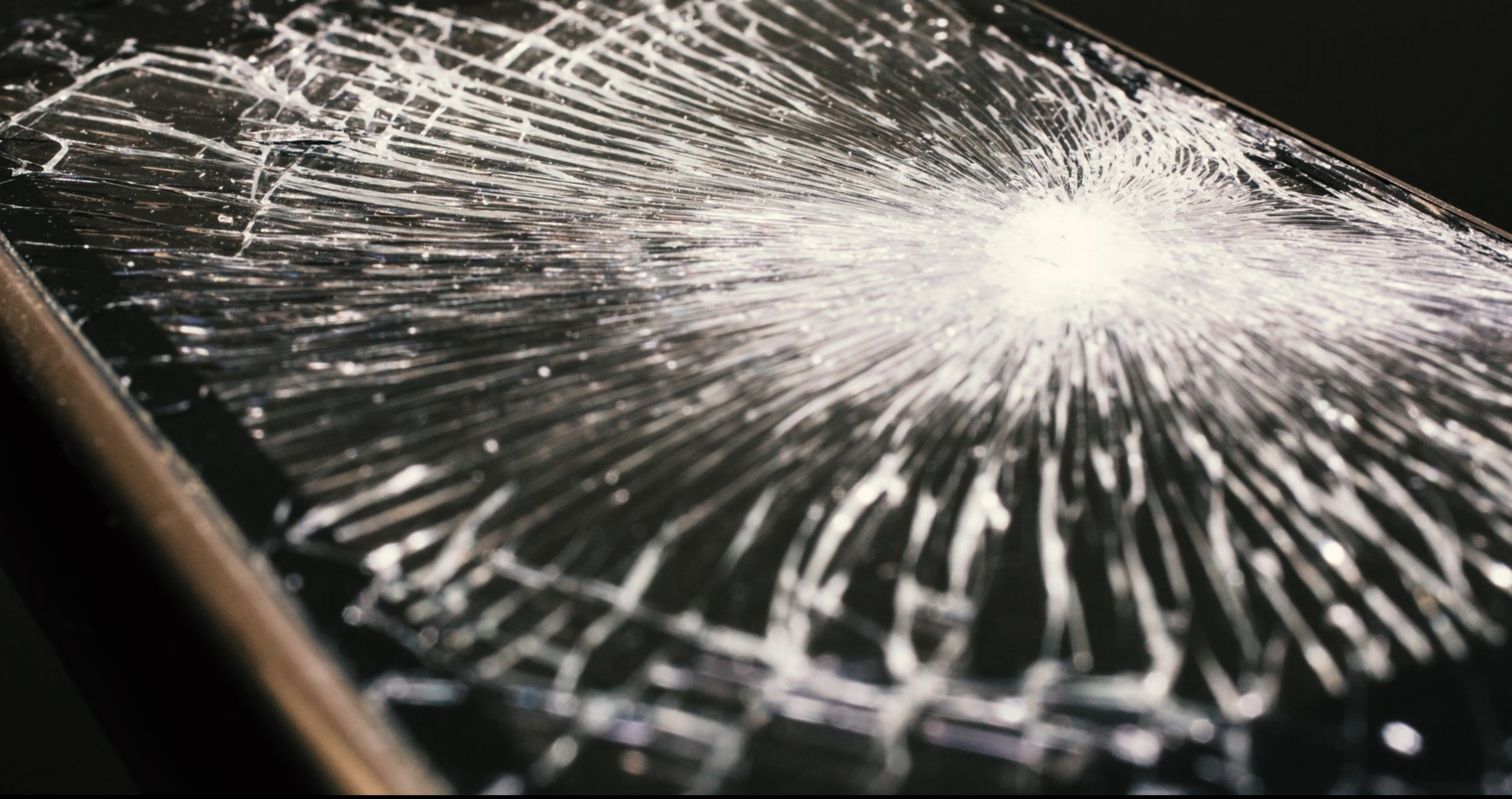
Inkjet 4D Print
TOG (SIGGRAPH2023)

Self-healing UI:

Mechanically and Electrically Self-healing Materials for Sensing and Actuation Interfaces

Koya Narumi*, Fang Qin*, Siyuan Liu, Huai-Yu Cheng, Jianzhe Gu, Yoshihiro Kawahara, Mohammad Islam, Lining Yao
Carnegie Mellon University & The University of Tokyo





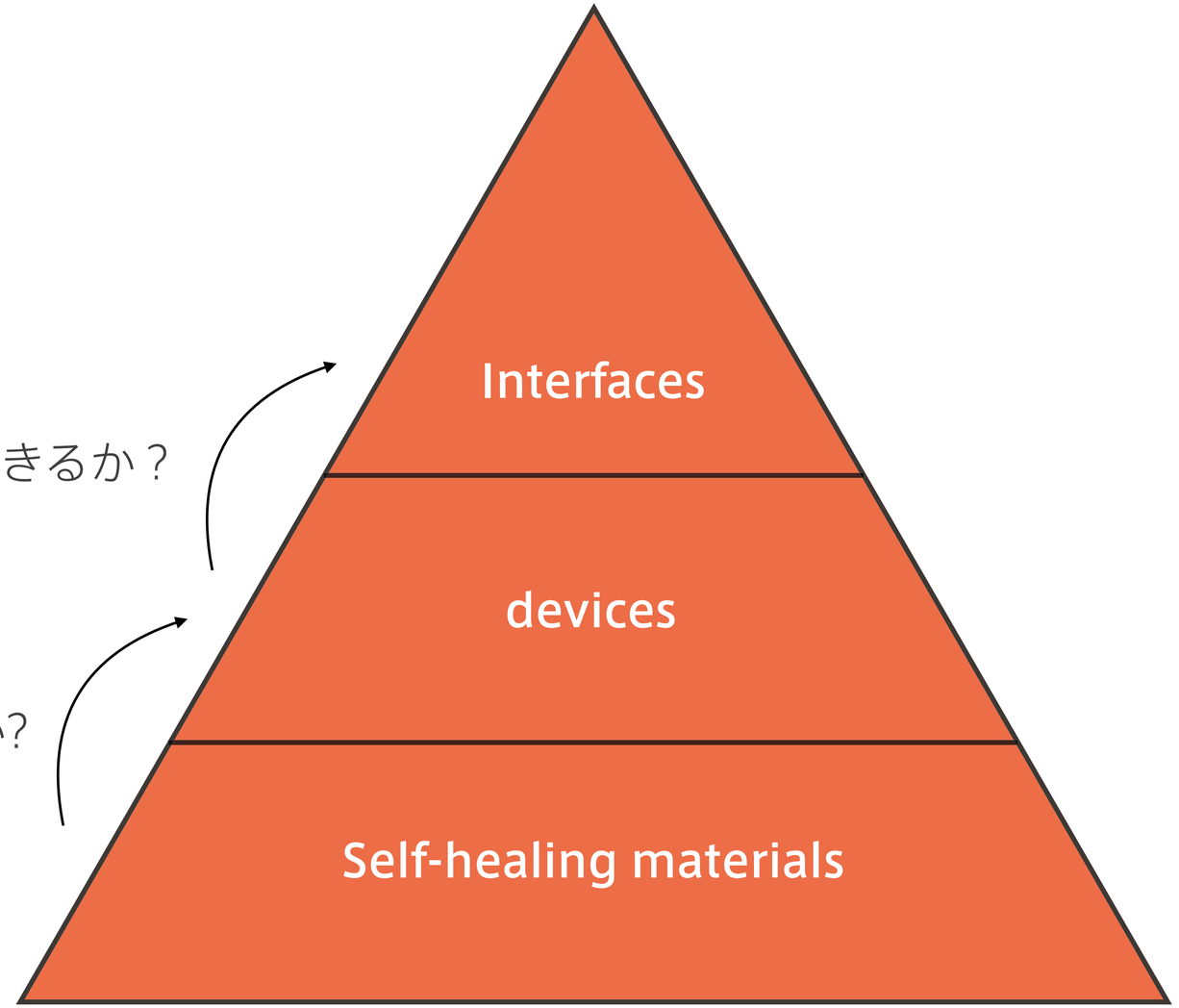
既存のインタフェースは精密だが、一度壊れると治らない

生物には傷を「治す」事例が存在する

「治るインタフェース」に向けた課題

2. **デザインスペース**
   修復機能をただ「治る」以上にどう活用できるか？

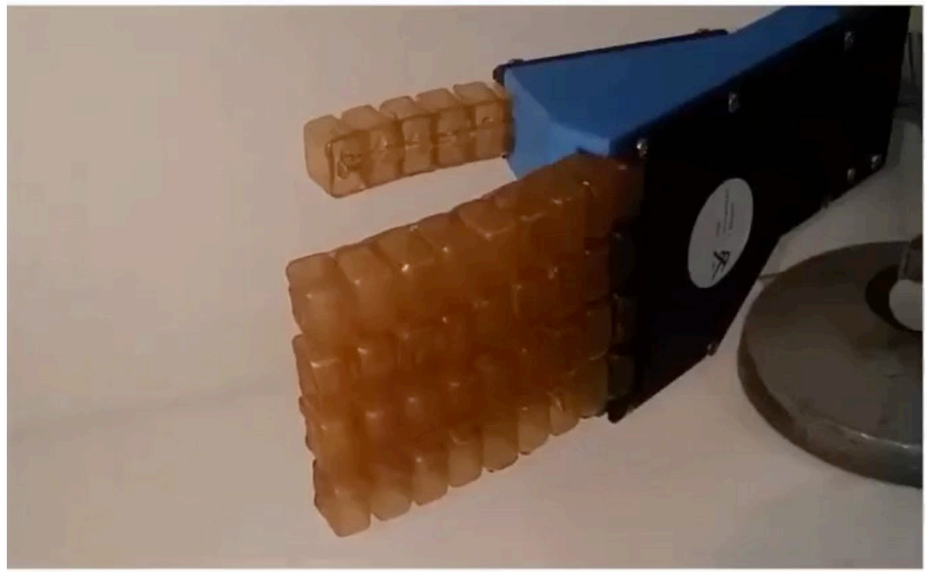
1. **作製手法**
   デバイスに対して修復機能をどう付与するか?

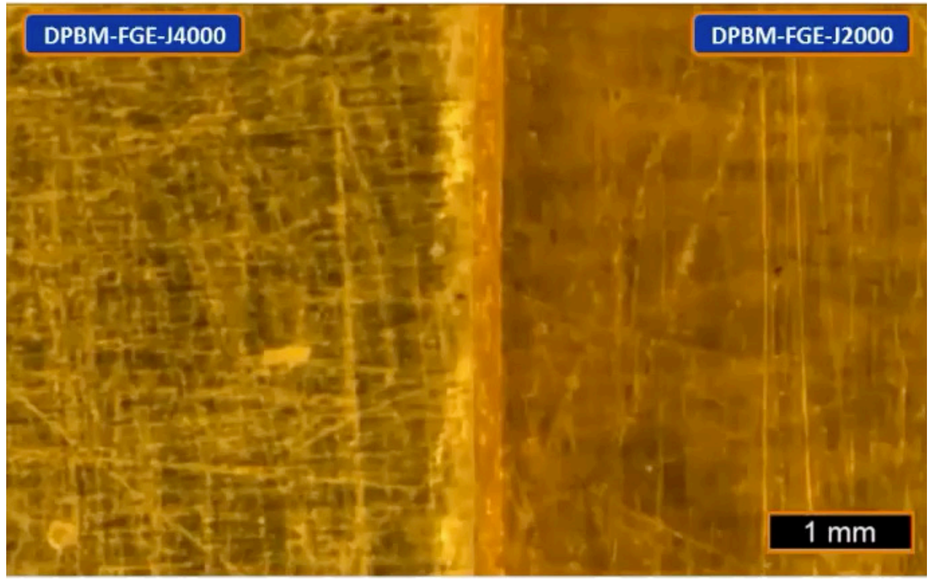



SELF-HEALING UI
CARNEGIE MELLON UNIVERSITY & UNIVERSITY OF TOKYO

Materials & Fabrication

自己修復材料とは何か



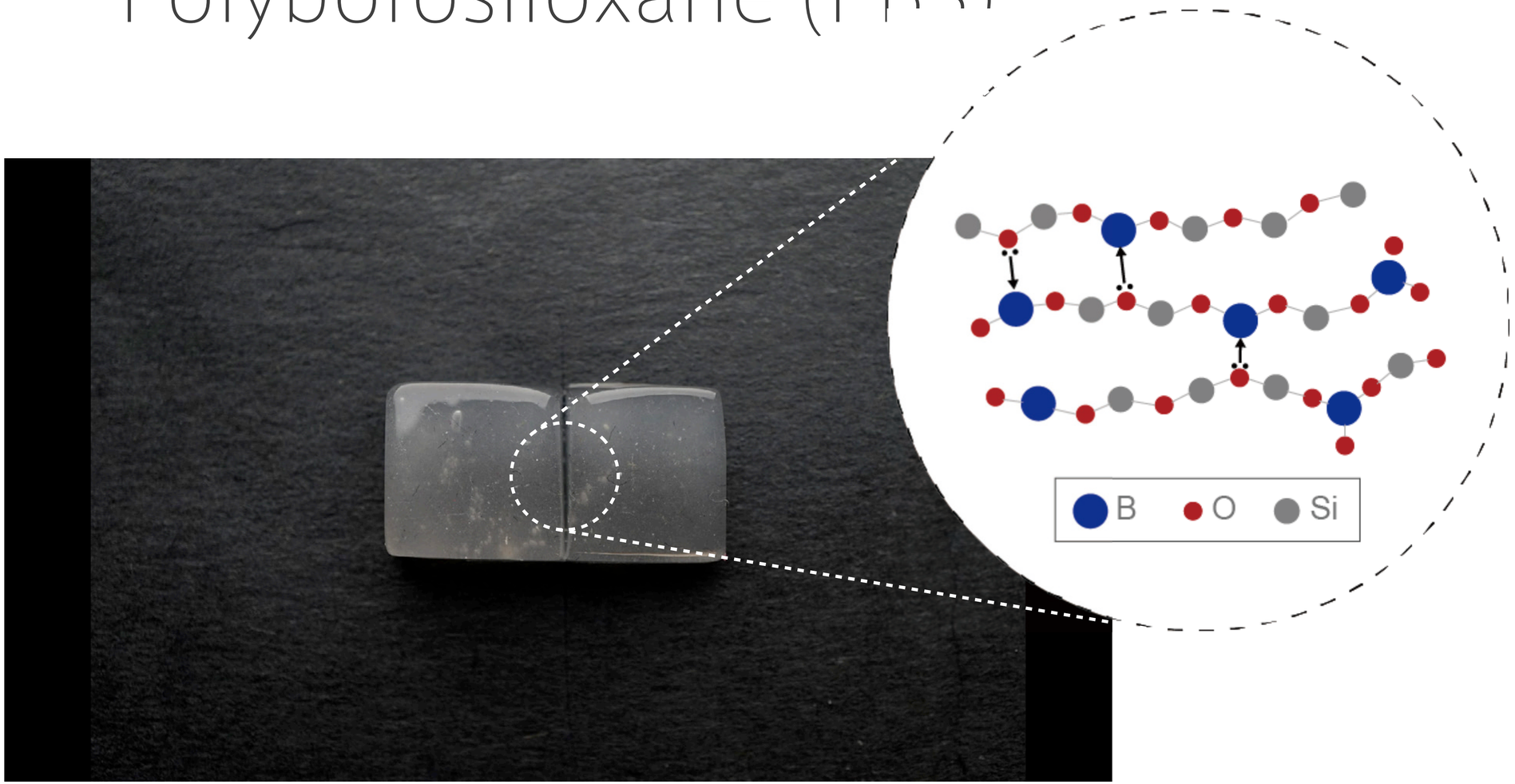


[1]

自己修復ポリマーとは、**機械的故障の後でも物理的/化学的に再結合できる**ポリマー

[1] Terryn et al., *Science Robotics*, 2017.

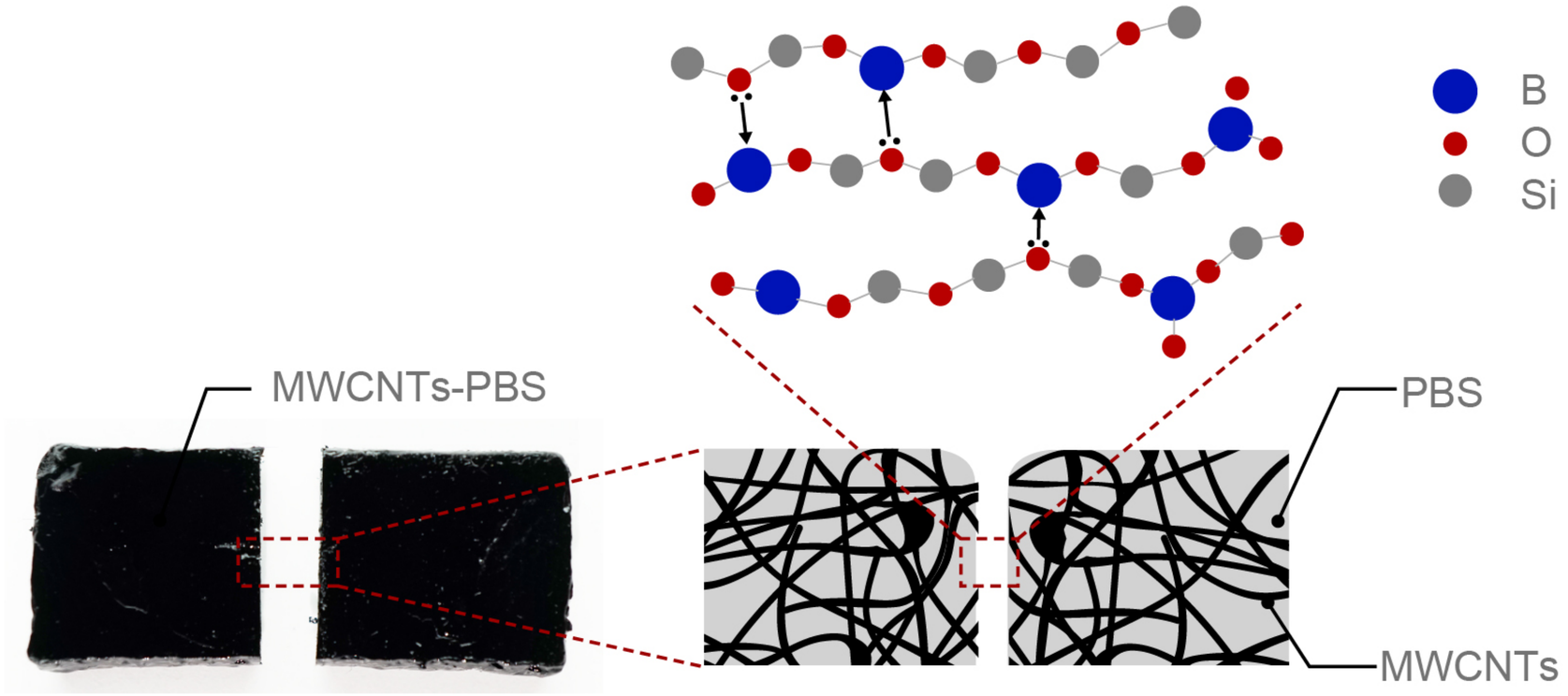
Polyborosiloxane (PBS)



素材の追加や刺激なしに6時間で自己修復する
B-O間の配位結合により**何度でも修復可能**

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

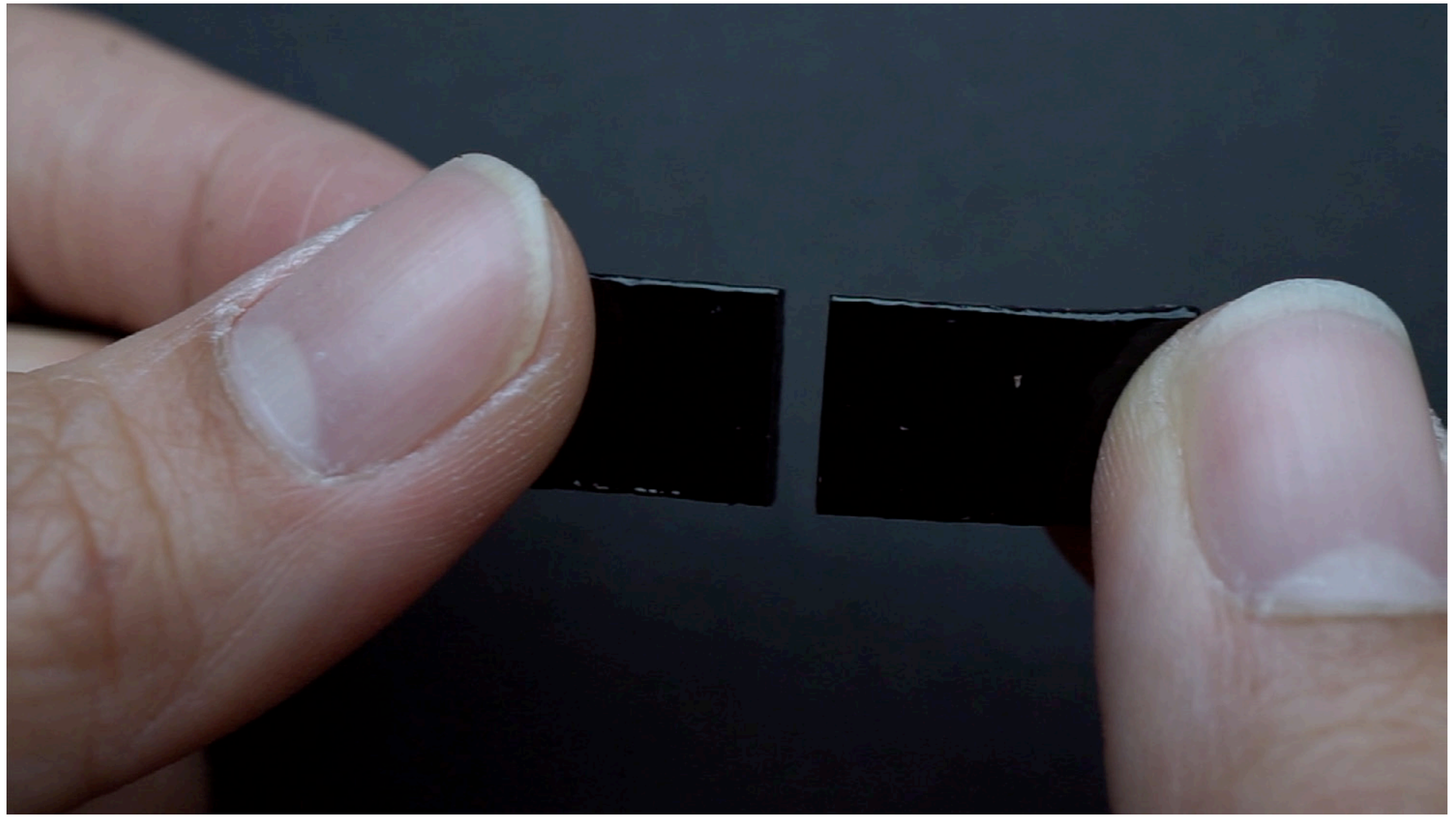
MWCNTs-PBS



素材が「溶ける」問題と導電性付与の問題を、**カーボンナノチューブの分散**により解決
従来の導電性PBSの合成方法に比べ、インタフェースを作るのに必要な**大量かつ簡単な作製手法を提案**

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

修復プロセス



MWCNTs-PBSは接続後10秒で自重を支えられる程度に修復し、6時間後には完全に修復する

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

PBSとMWCNTs-PBSの複合システム

PBS

Insulator

+

MWCNTs-PBS

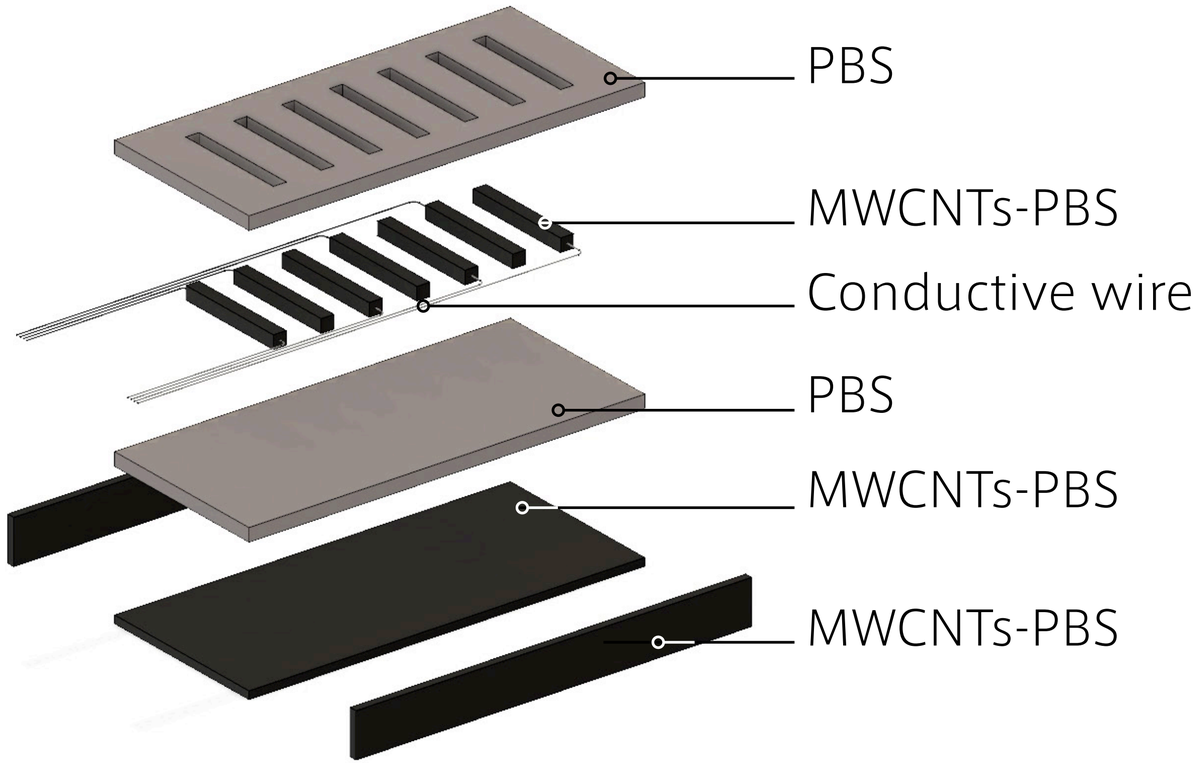
Conductor
Mechanical support

=

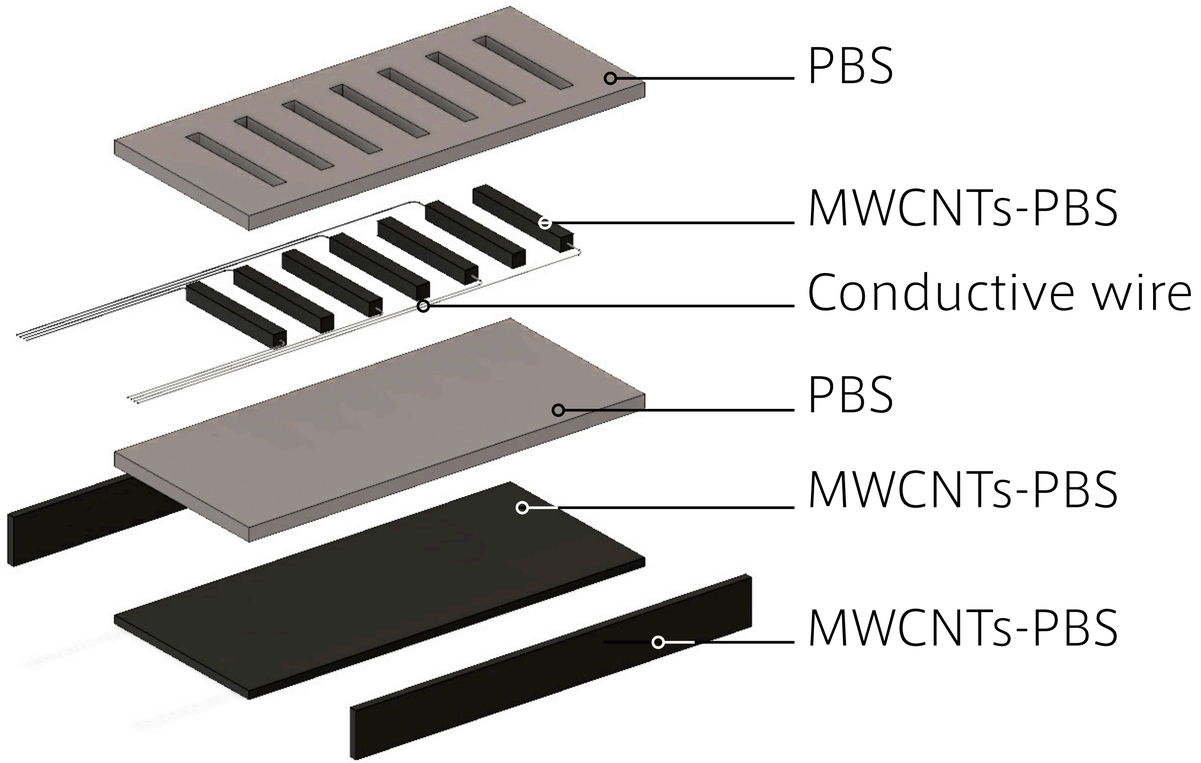
Hybrid healable device

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

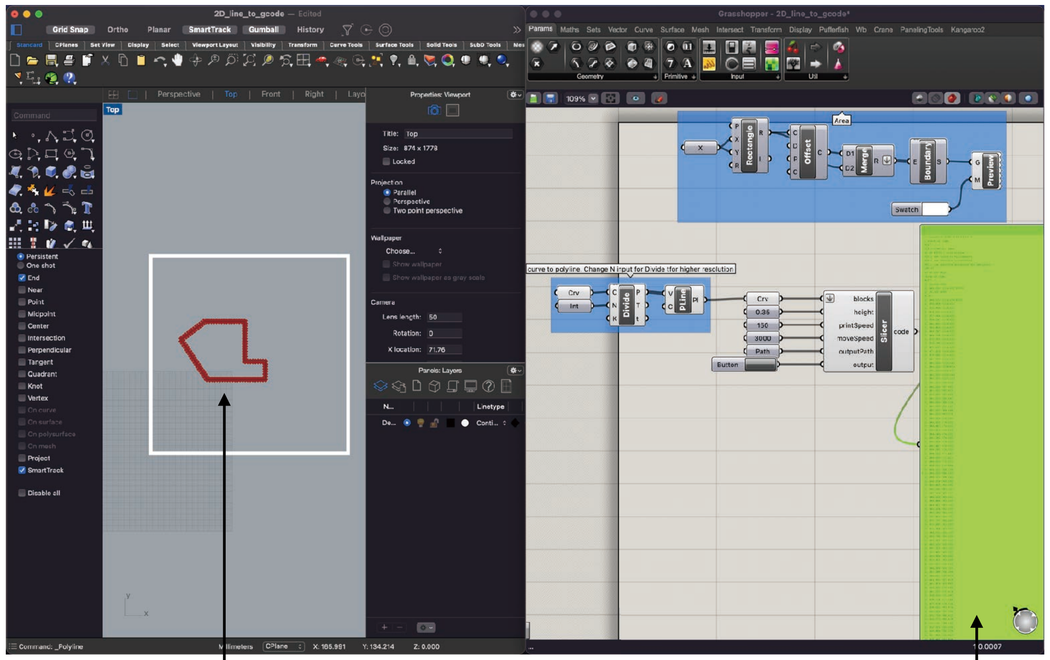
積層型ファブリケーション



機械的・電気的修復により、**接着剤を使わずに積むだけでファブリケーションが可能**

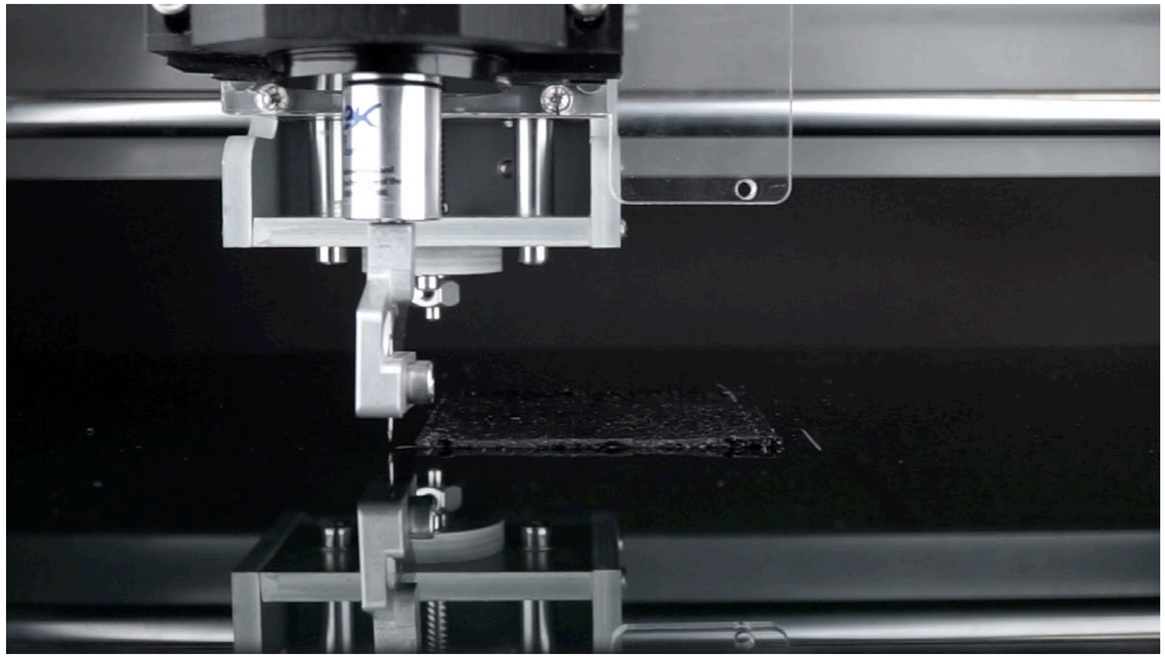

PBS
MWCNTs-PBS
Conductive wire
PBS
MWCNTs-PBS
MWCNTs-PBS

カスタムCNCによる製造



切断したい形状

出力された改造Gコード

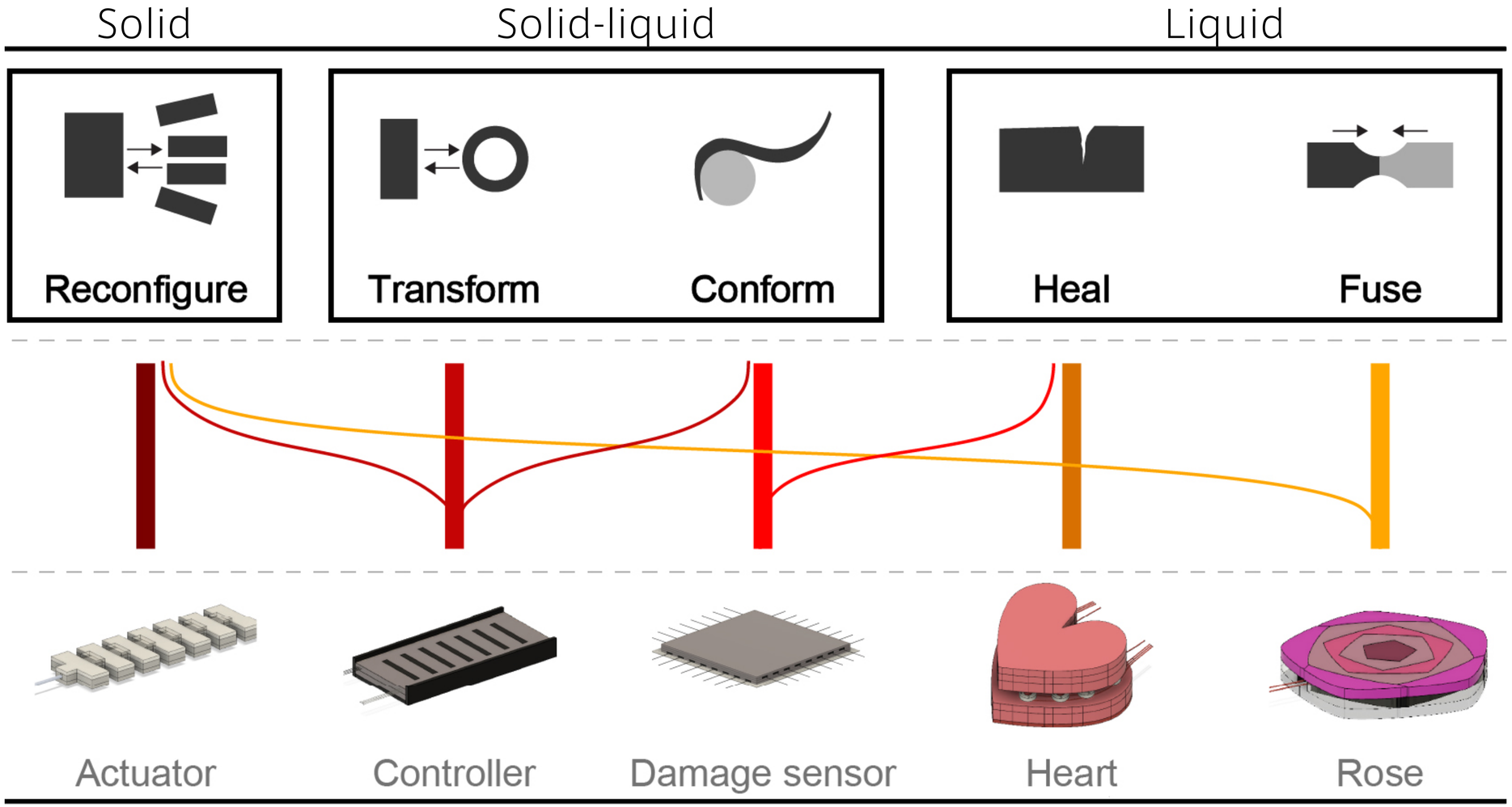


ドラッグナイフを搭載したCNCに改造Gコードを送信するスライサを作製

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

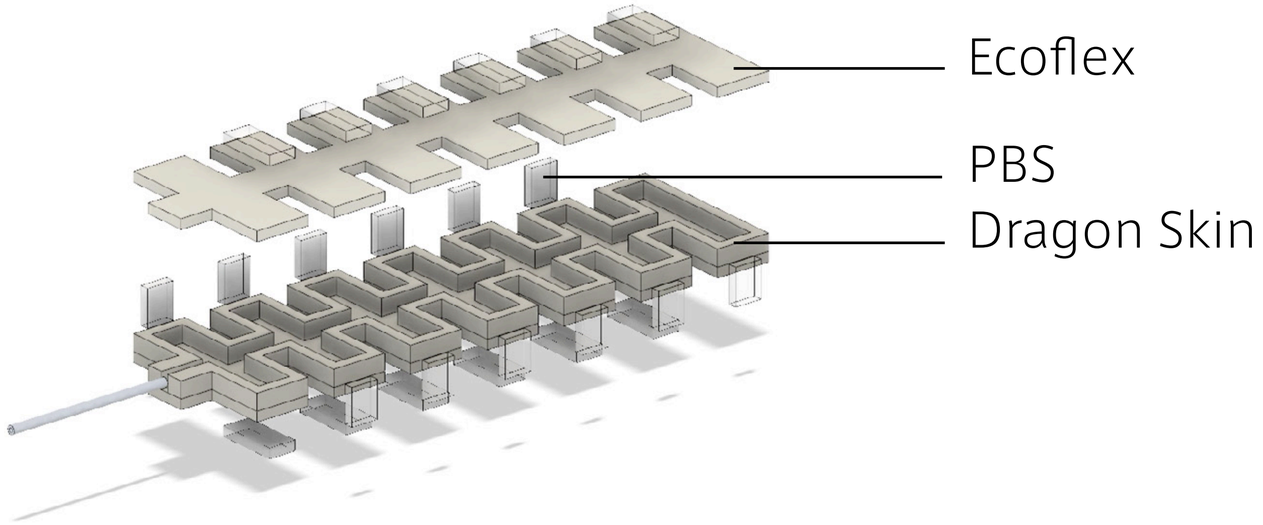
Applications

Design Space for Self-healing UI



Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

Reconfigurable Actuator



空気圧アクチュエータの節が修復素材でできている

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

Reconfigurable Actuator

“C” curve

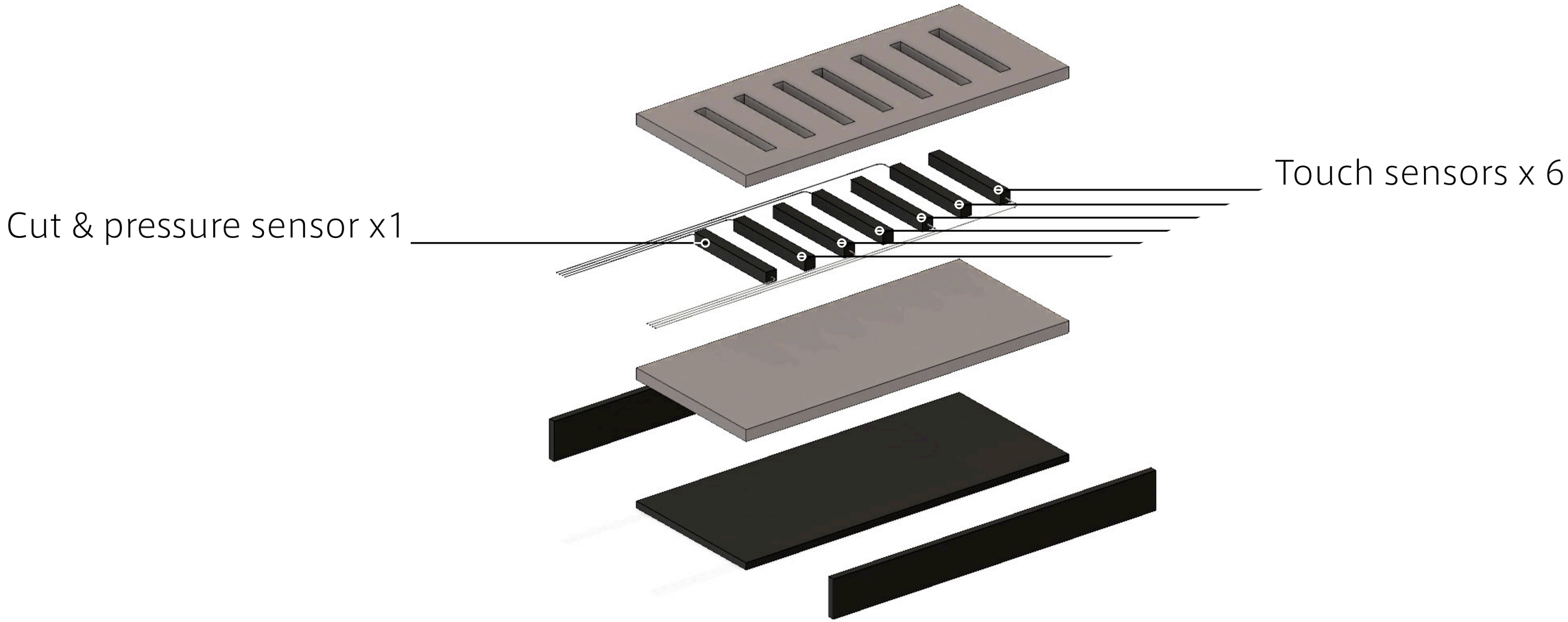
“S” curve

Short “C” curve

形状と動きを**再構成可能**なアクチュエータ

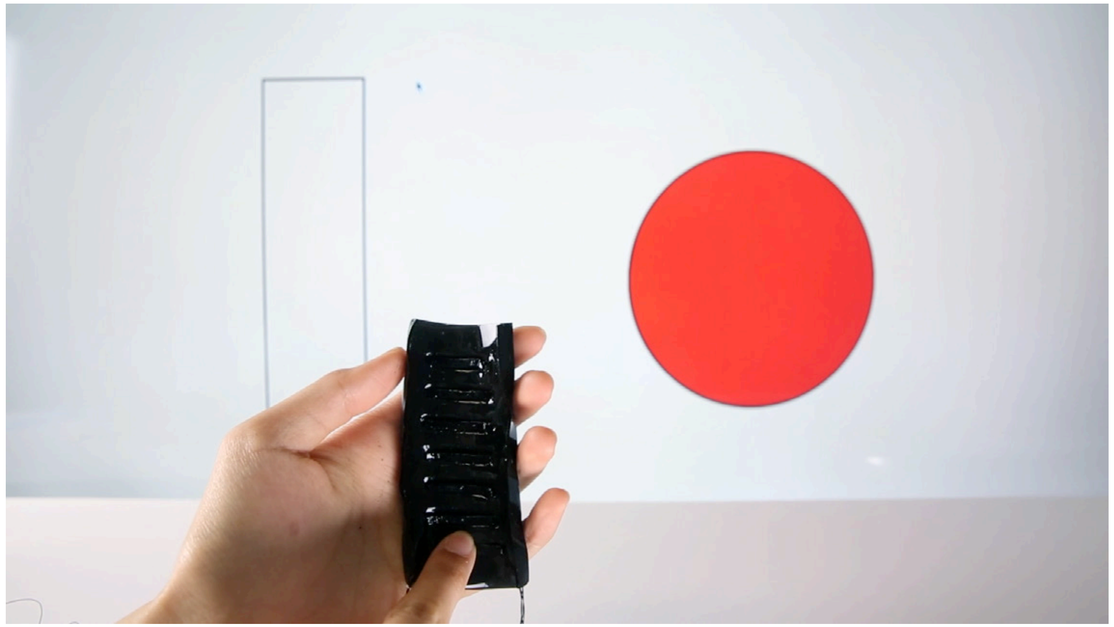
Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

Transformative Soft Controller

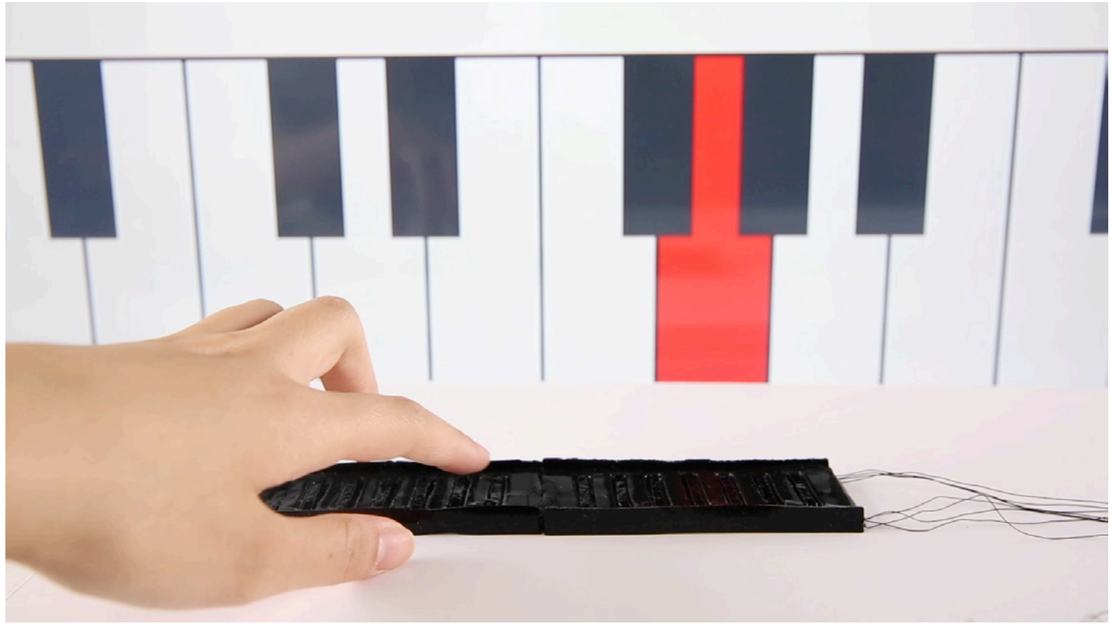


Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

Transformative Soft Controller



通常のモード



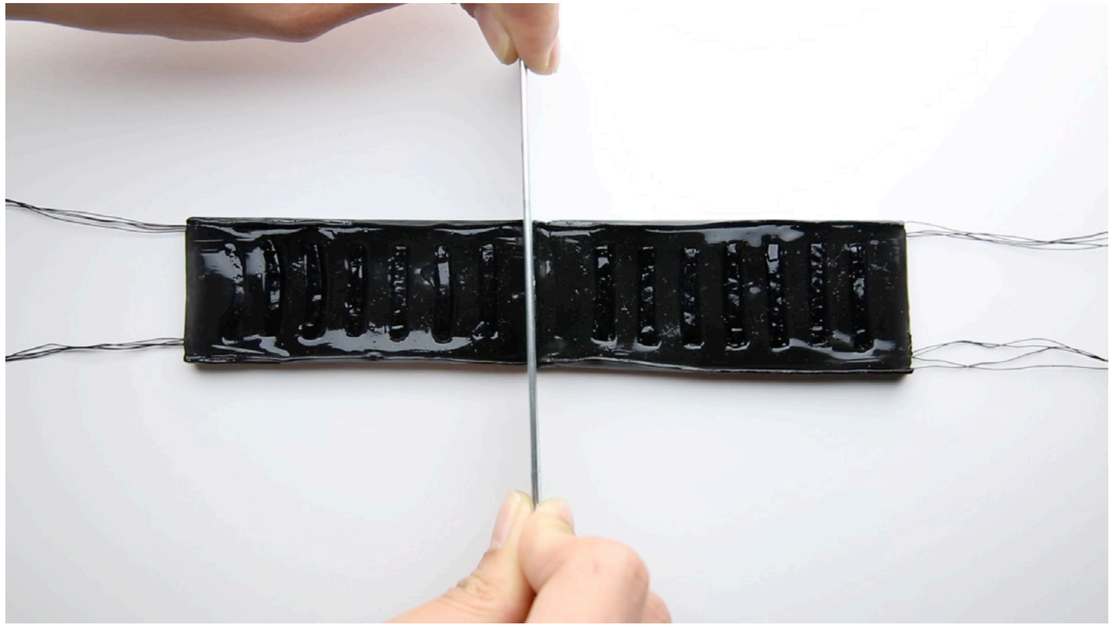
ロングモード

ユーザの要求に合わせて、**直観的な形状変化**でモードを変えるコントローラ

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

Transformative Soft Controller

腕輪モード

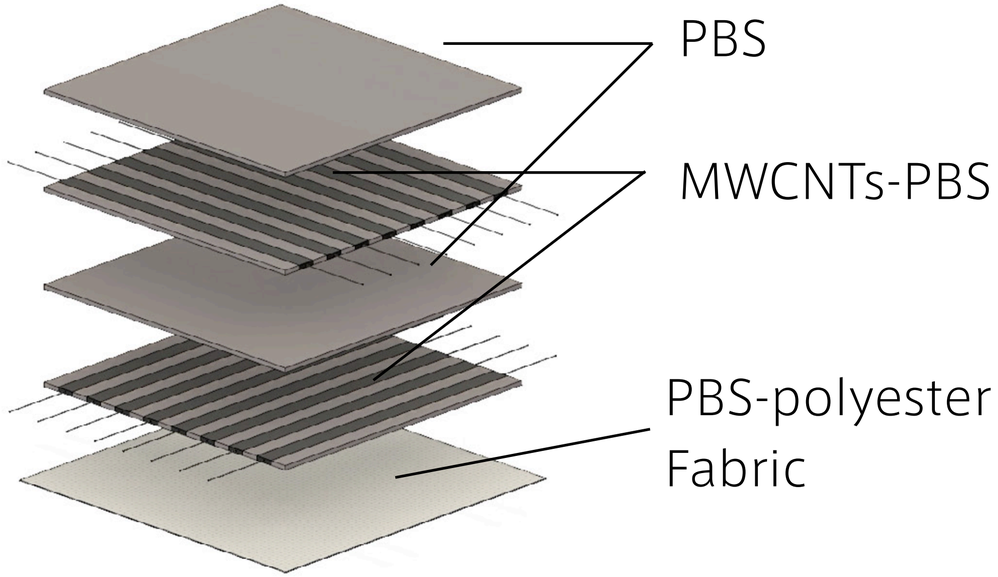


切断モード

ユーザの要求に合わせて、**直観的な形状変化**でモードを変えるコントローラ

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

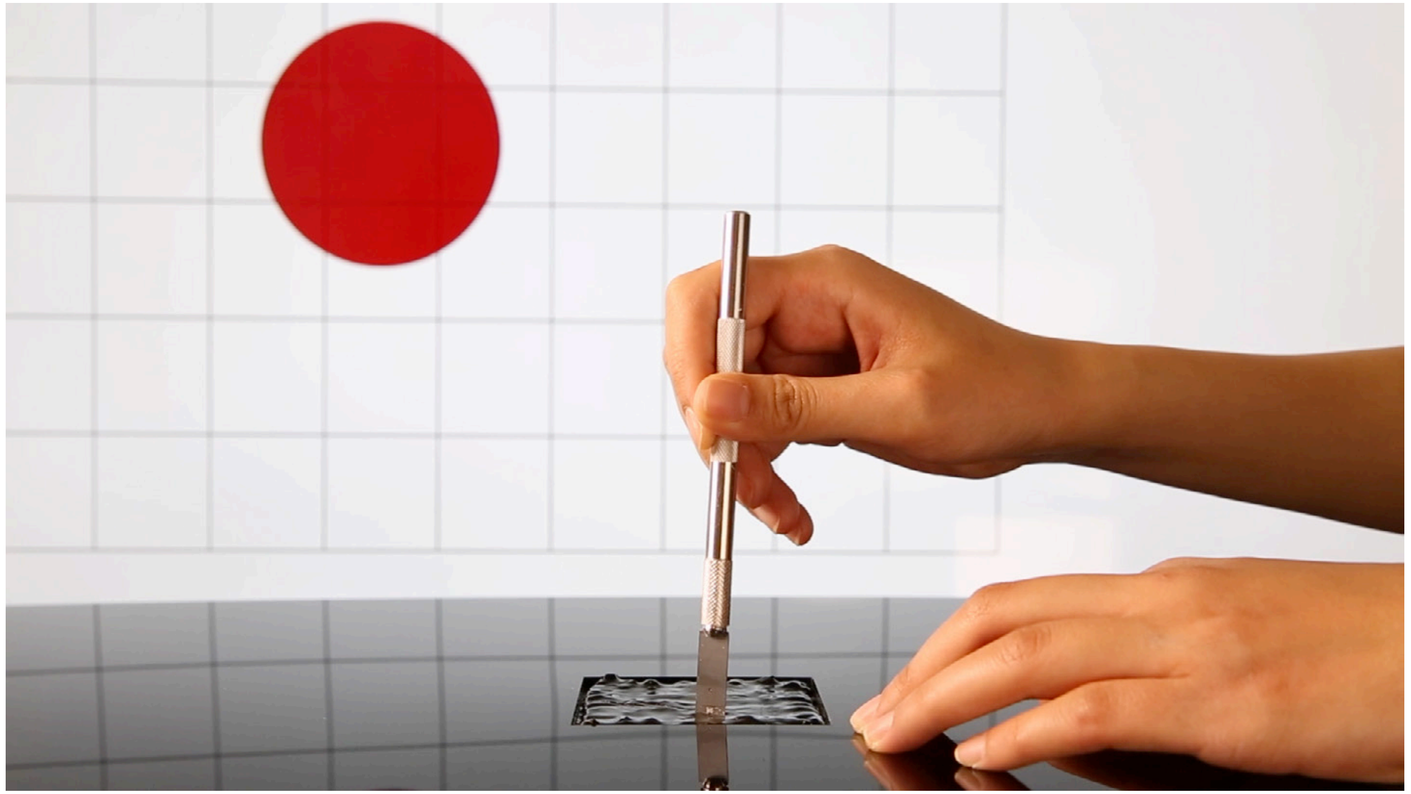
Conformable Damage Sensor



第二の肌として**着用者の怪我を検知するセンサ**

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

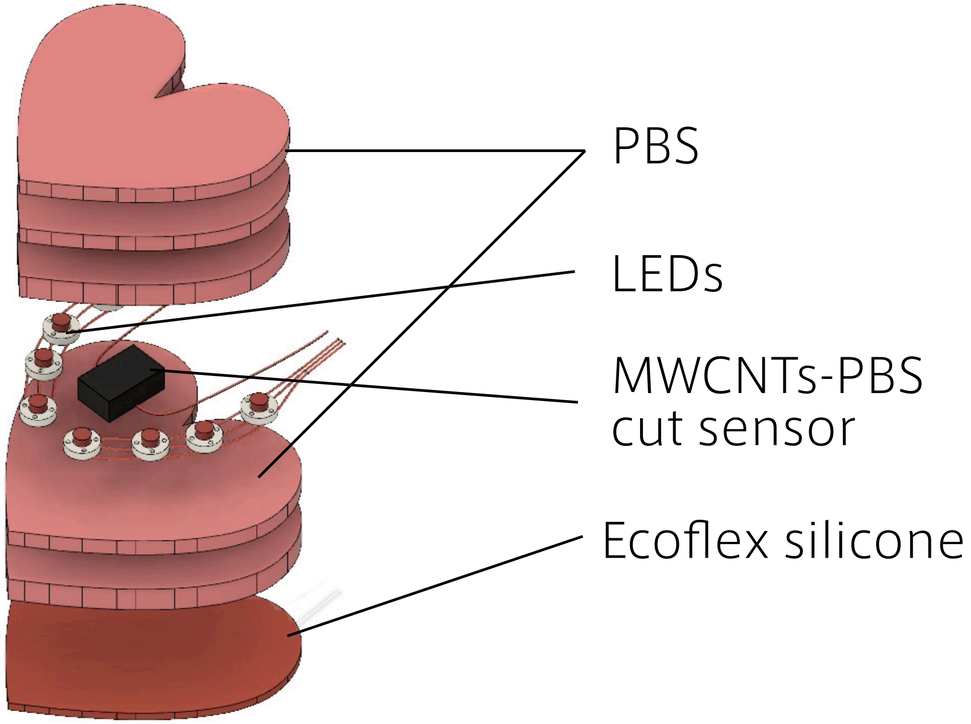
Conformable Damage Sensor



センサは自分自身の破壊を検知した後で、修復し再び動作する

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

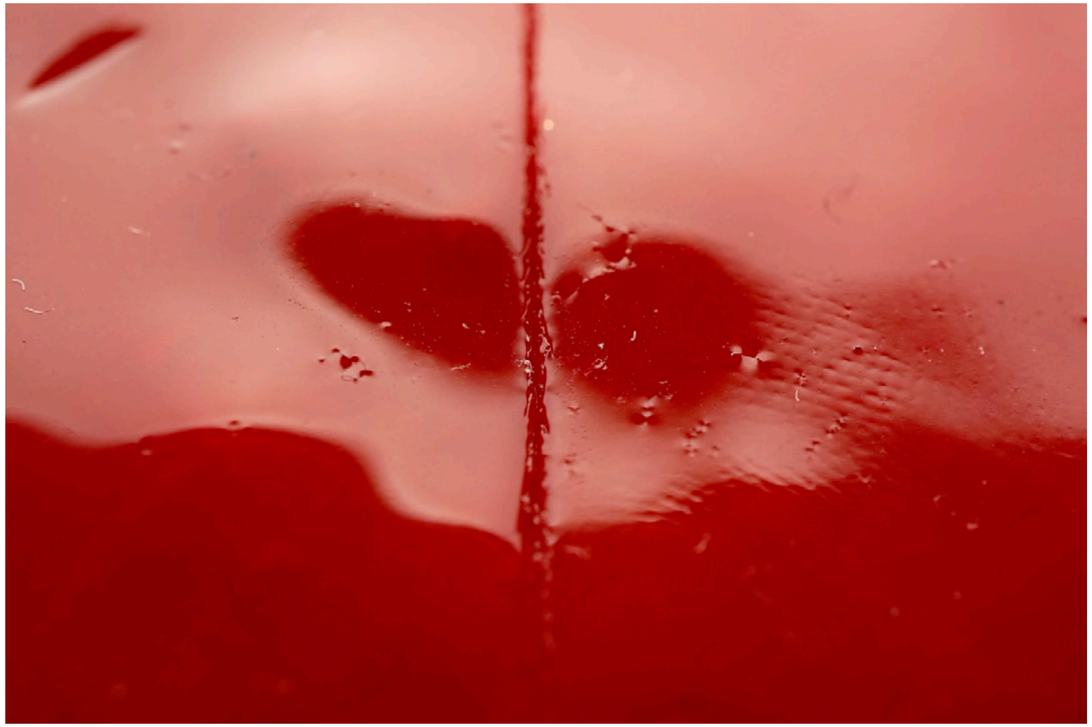
Healing Heart



導電性と機械特性の両方を**修復**できるデバイス

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

Healing Heart

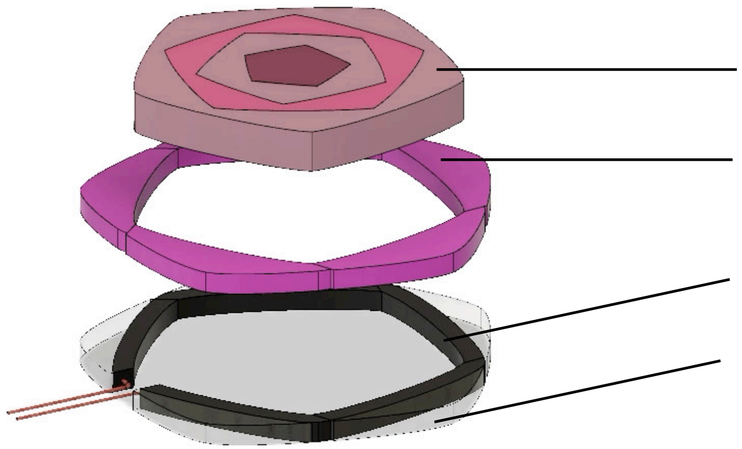


Time-lapse imaging for 6 h

導電性と機械特性の両方を**修復**できるデバイス

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

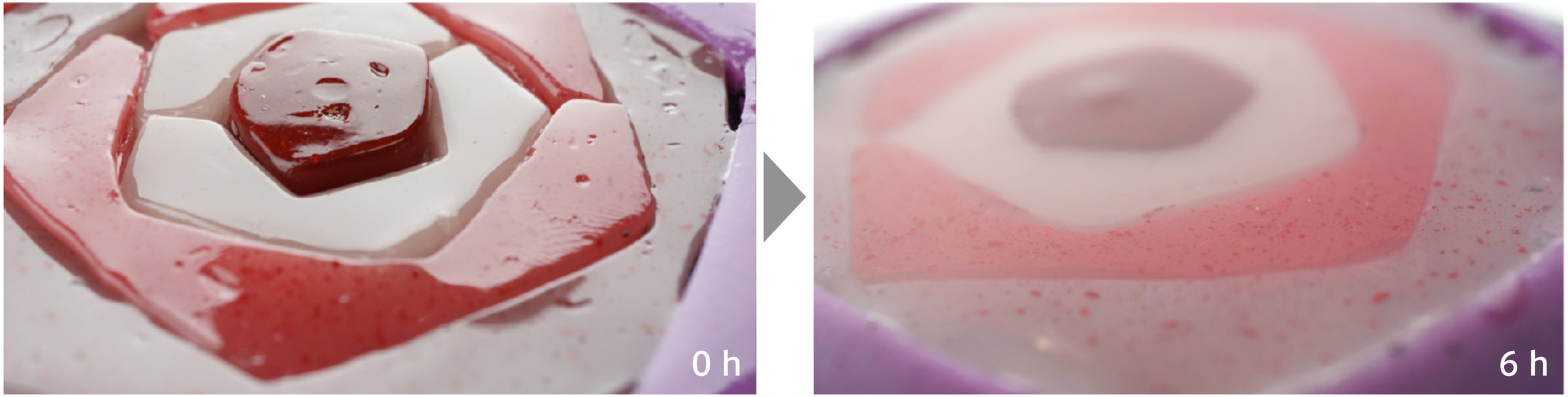
Fusing Rose Puzzle



複数の異なる部品が**溶けて**1つにつながる

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

Fusing Rose Puzzle

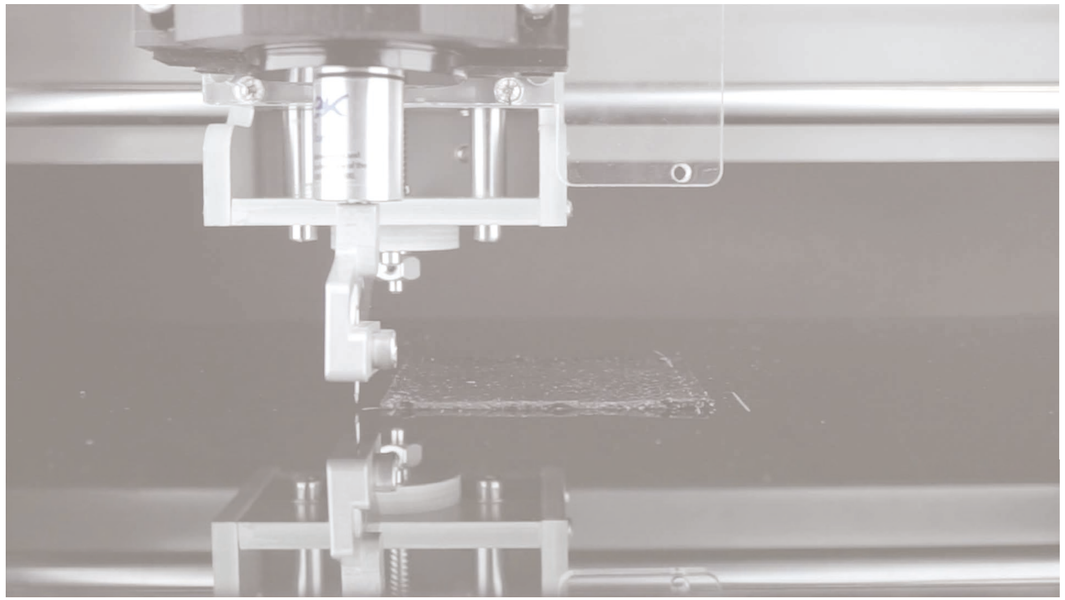


複数の異なる部品が**溶けて**1つにつながる

Narumi*, Fang*, Liu, Cheng, Gu, Kawahara, Islam, & Yao, Self-healing UI, UIST2019.

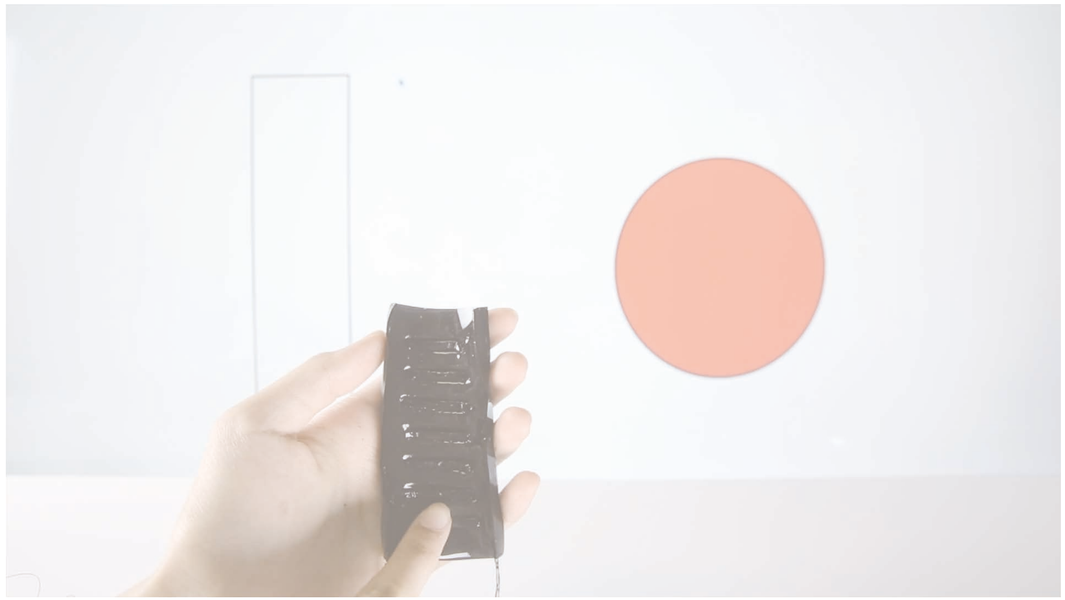
まとめ

1. 計算製造



- PBSとMWCNTs-PBSの複合システム
- 修復素材をデバイスに加工するための**製造システム**

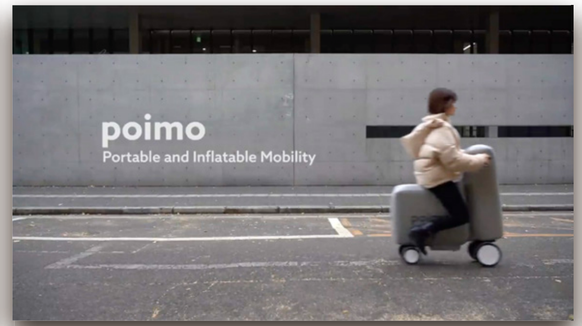
2. マテリアル・インタラクション



- **「ただ治る」以上**のインタラクション

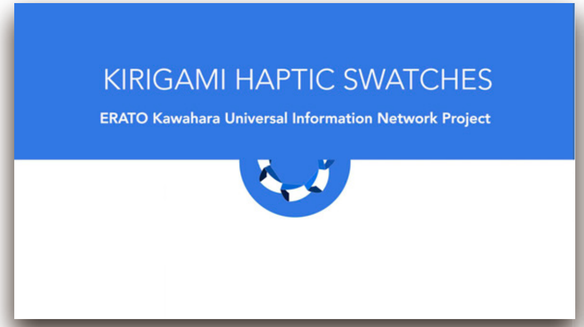
Liquid Pouch Motors
ICRA2017 + RoboSoft2020

Self-healing UI
UIST2019



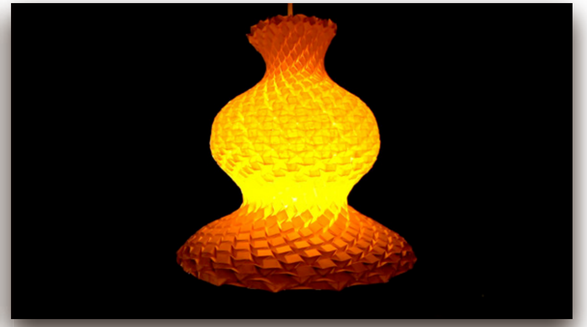
poimo
CHI EA 2020 & UIST2020

Pop-up Print
UIST2020



Kirigami Haptic Swatches
CHI2020

Flower Jelly Printer
CHI2021

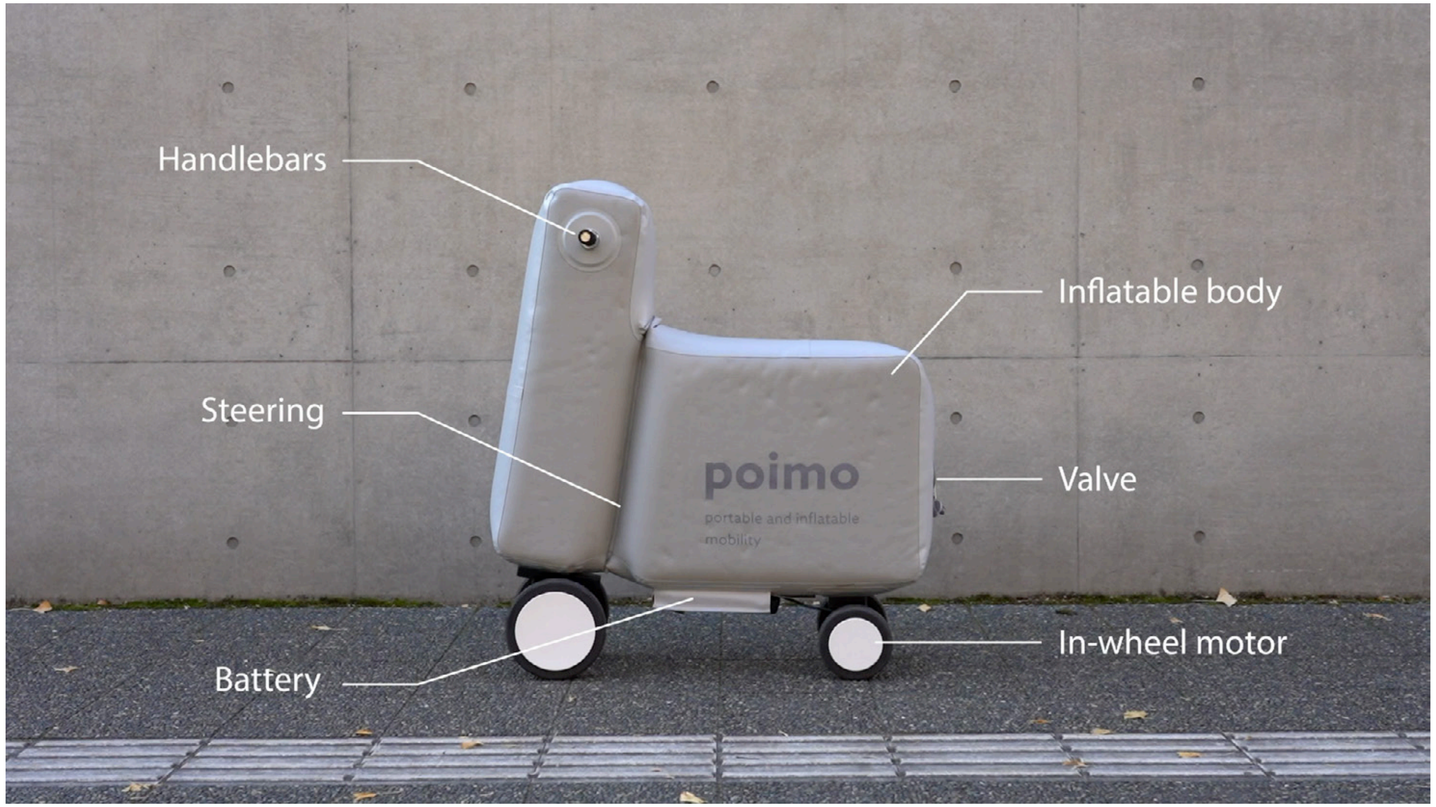


Crane
TOCHI (CHI2023)

Inkjet 4D Print
TOG (SIGGRAPH2023)


poimo
Portable and Inflatable Mobility

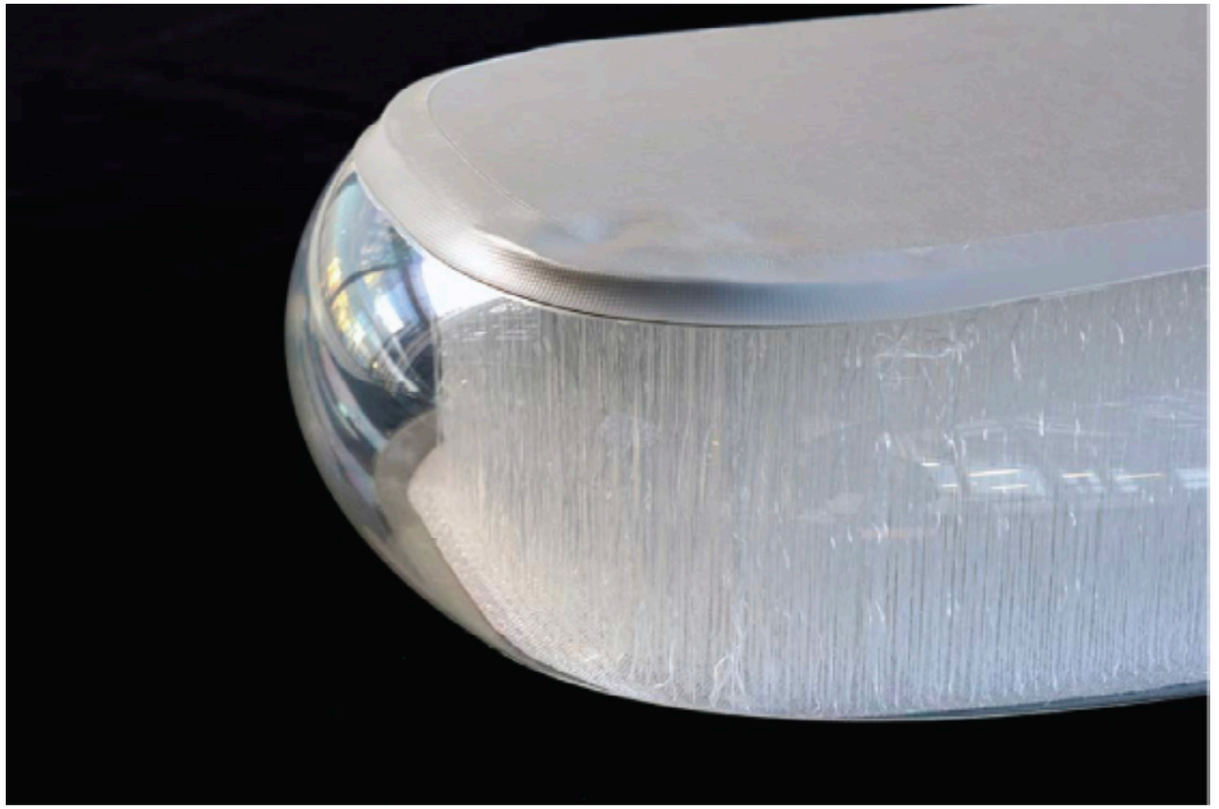
poimo (第一世代)



やわらかく、軽く、インフレータブルなパーソナルモビリティ
小さくたたんで運び、大きく展開して乗る

Sato et al., Soft yet Strong Inflatable Structures for a Foldable and Portable Mobility, CHI EA 2020.

Drop-stitch Fabric



風船をたくさんの糸でつなぎ合わせた**ドロップステッチ**という素材
ほとんど膜と同じくらい軽いのに、人間を支えられるくらい頑丈

Sato et al., Soft yet Strong Inflatable Structures for a Foldable and Portable Mobility, CHI EA 2020.

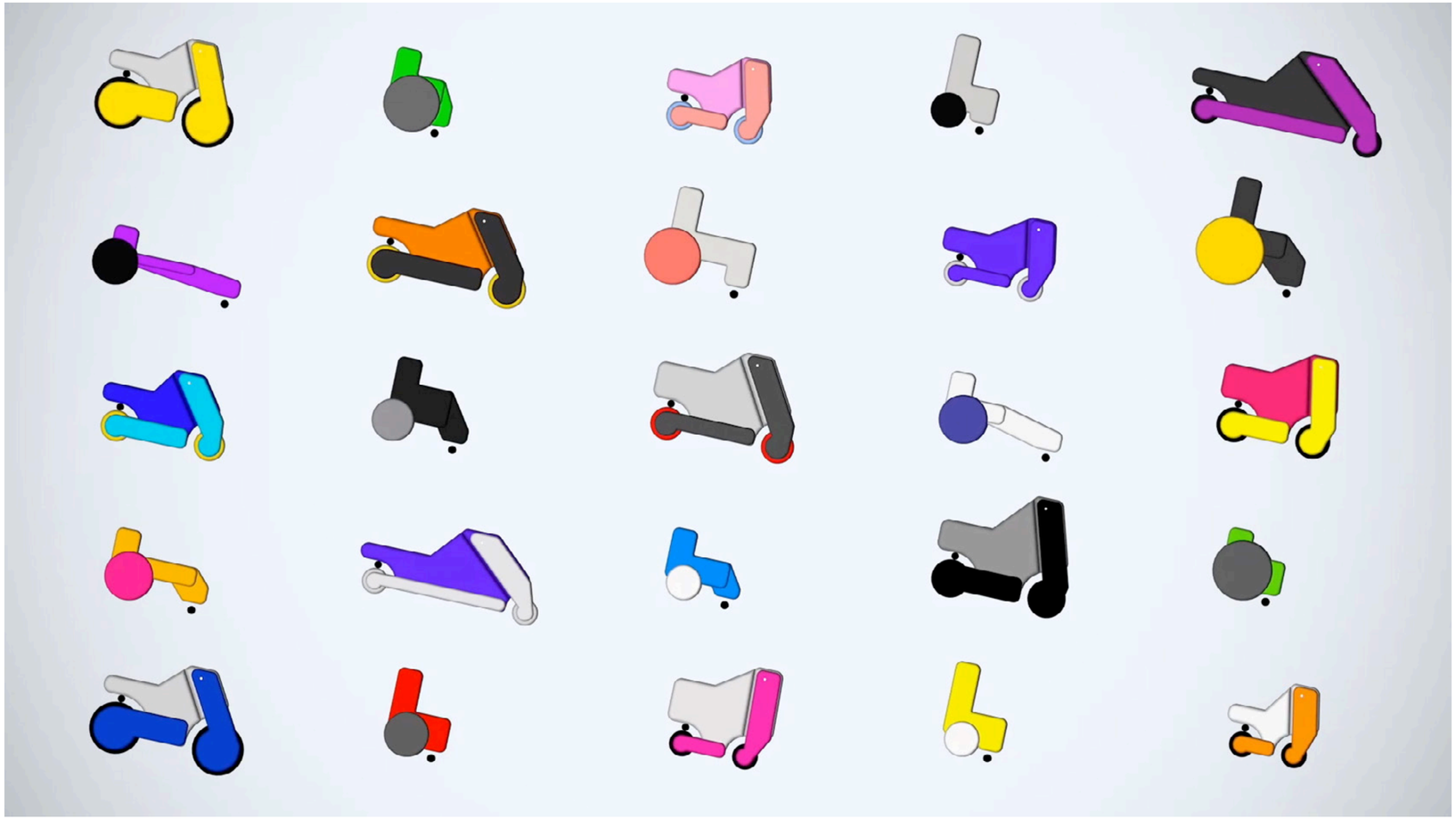
poimo第一世代: **膨らむ**モビリティ

↓

poimo第二世代: **個人に合わせて作れる**モビリティ

Sato et al., Soft yet Strong Inflatable Structures for a Foldable and Portable Mobility, CHI EA 2020.

poimo (第二世代)



個々人に合わせてカスタマイズ可能な乗り物

Niiyama & Sato et al., poimo, UIST, 2020.

メルカリとの社会実験

初心者でも乗れる（世界まる見え [1]）

子供を含む100人以上が乗れる [2]

---

[1] 世界まる見え（2020/11/23放送回）

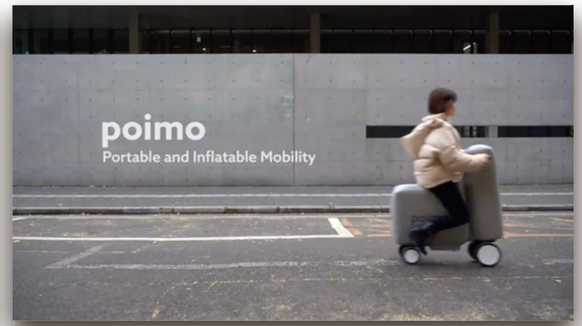
[2] mercari R4D YouTube動画より抜粋 https://youtu.be/lgMqZ7AzGCU

インクルーシブな技術としてのpoimo

誰でも受け入れられる「楽観的」なデザイン

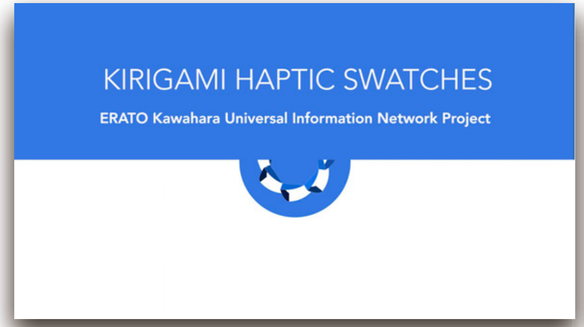
Liquid Pouch Motors
ICRA2017 + RoboSoft2020

Self-healing UI
UIST2019



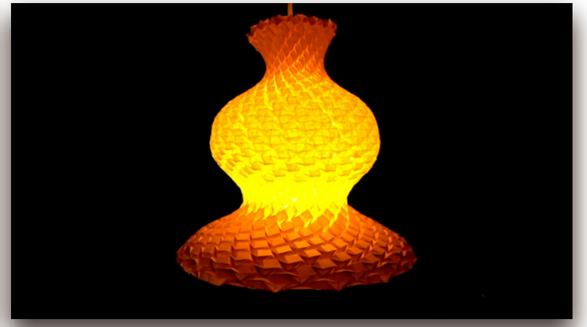
poimo
CHI EA 2020 & UIST2020

Pop-up Print
UIST2020



Kirigami Haptic Swatches
CHI2020

Flower Jelly Printer
CHI2021

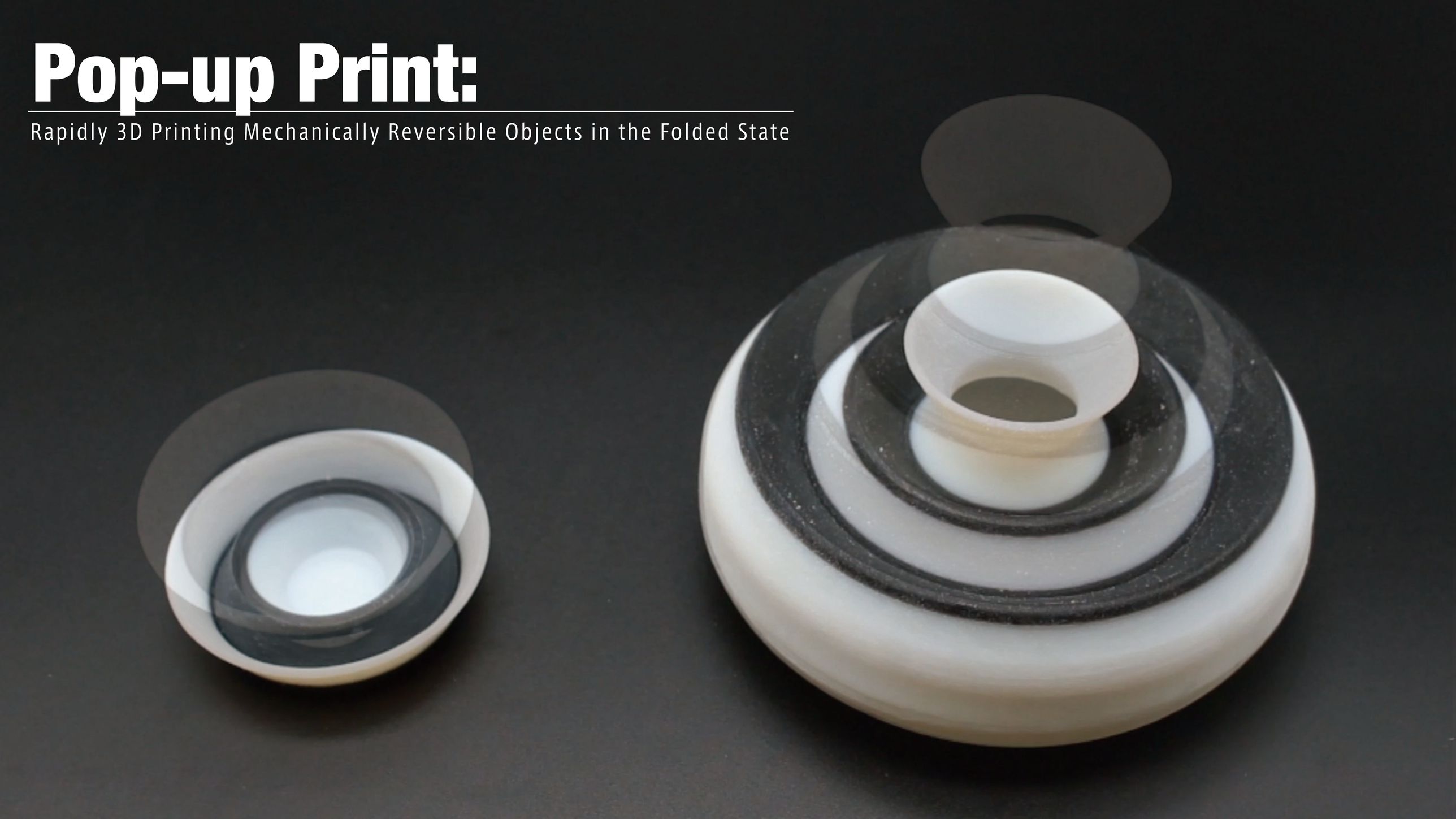


Crane
TOCHI (CHI2023)

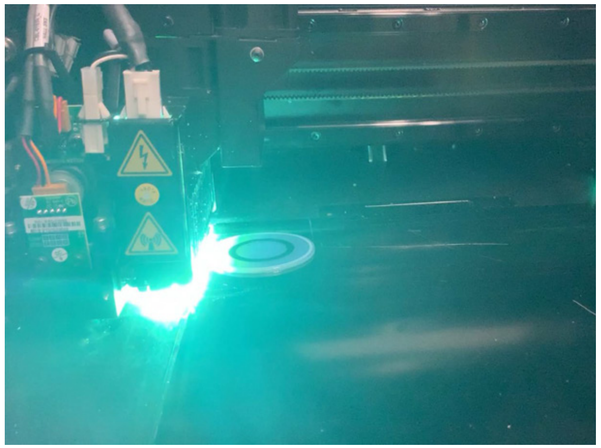
Inkjet 4D Print
TOG (SIGGRAPH2023)

Pop-up Print:

Rapidly 3D Printing Mechanically Reversible Objects in the Folded State

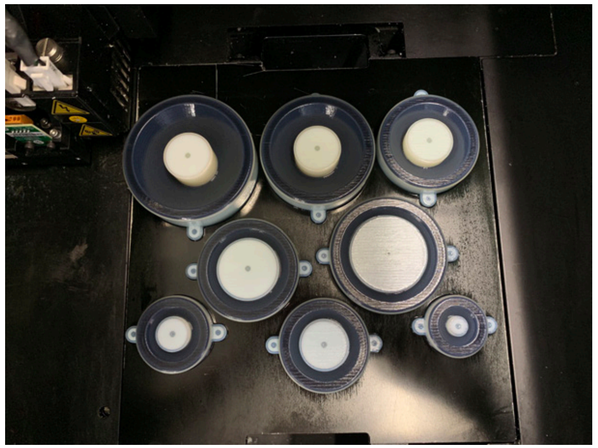


大きな構造物を印刷するときの問題点



①長い印刷時間

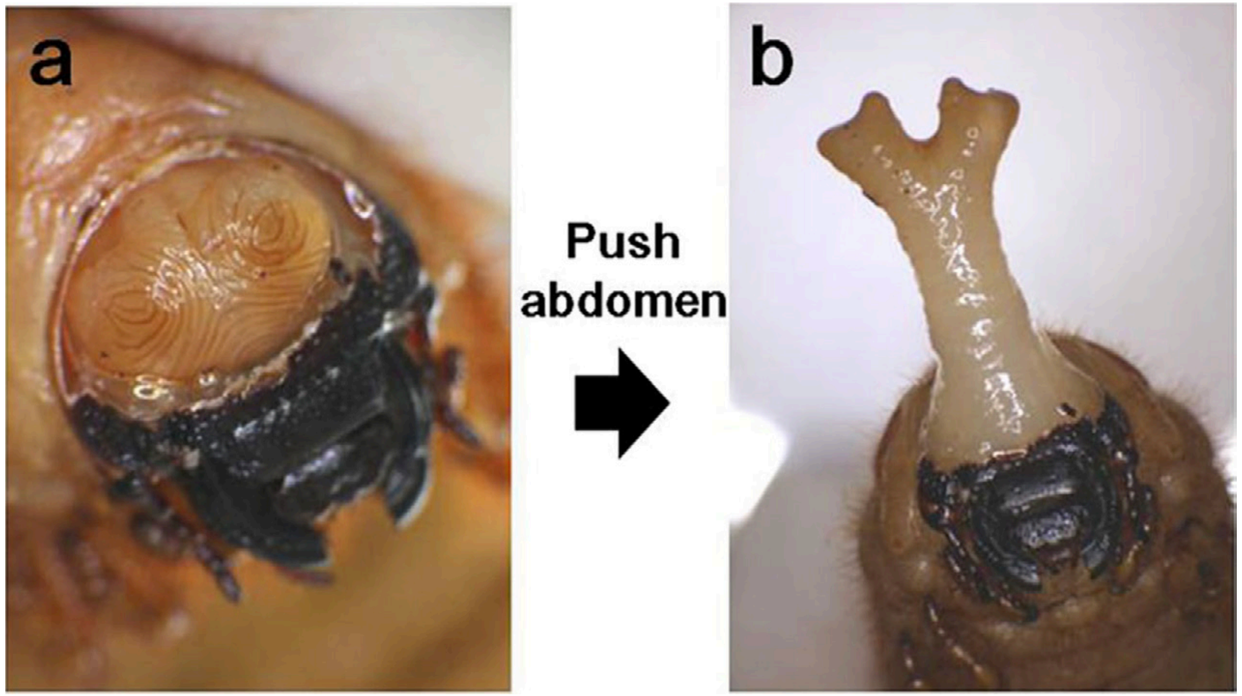
②サポート材による環境負荷



③収納

3Dプリントする構造物は**小さければ小さいほど良い**

カブトムシの「逆折紙」



[1]

サナギの中にいるカブトムシ　　成虫になる直前

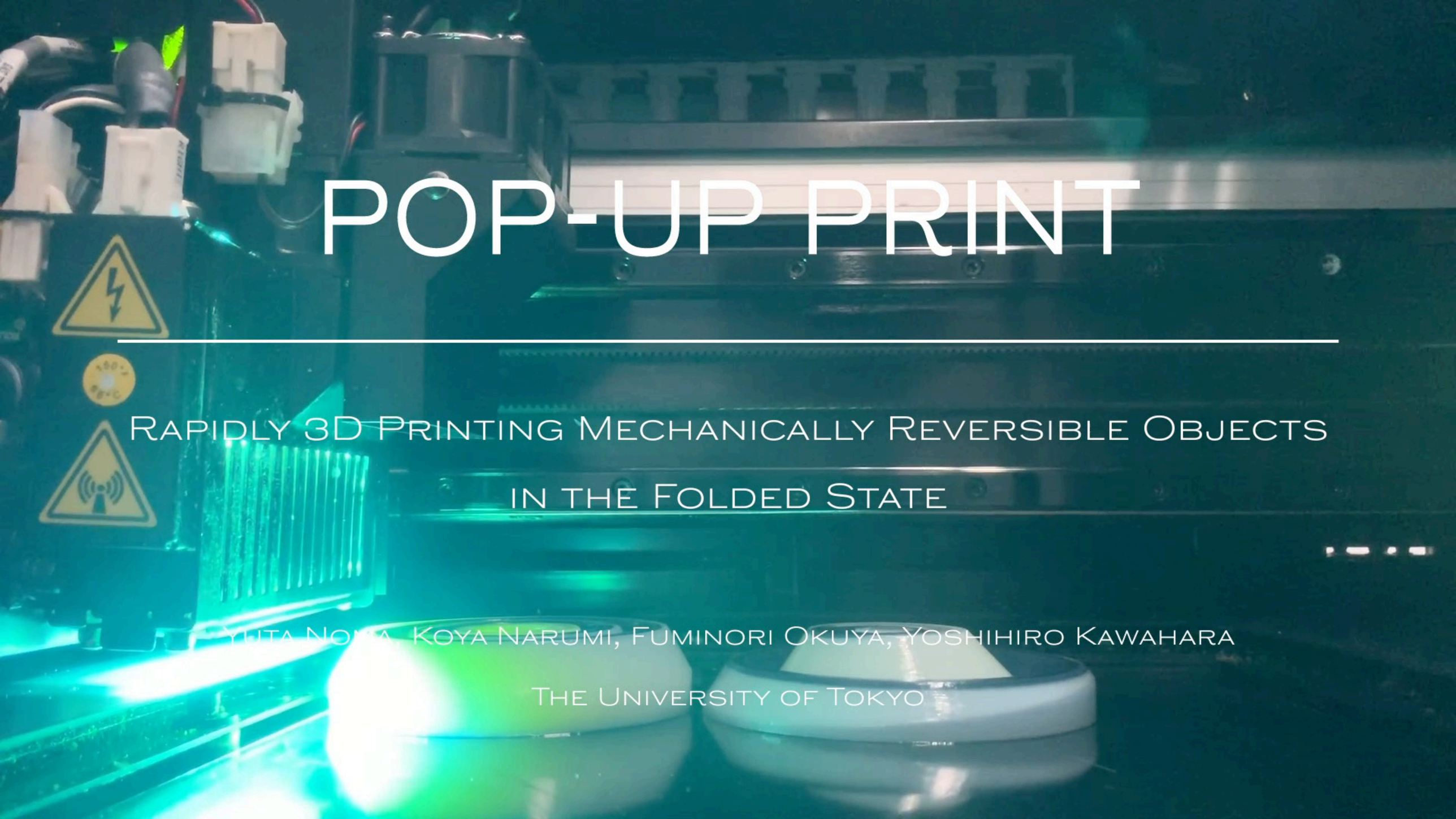
カブトムシのサナギは角を**折りたたんだ状態**で作る。これを**逆折紙**と呼ぶ [2]

---

[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)

「逆折紙」による3Dプリント

①構造物を**折りたたんだ状態で印刷**し、②できあがってから**展開する**



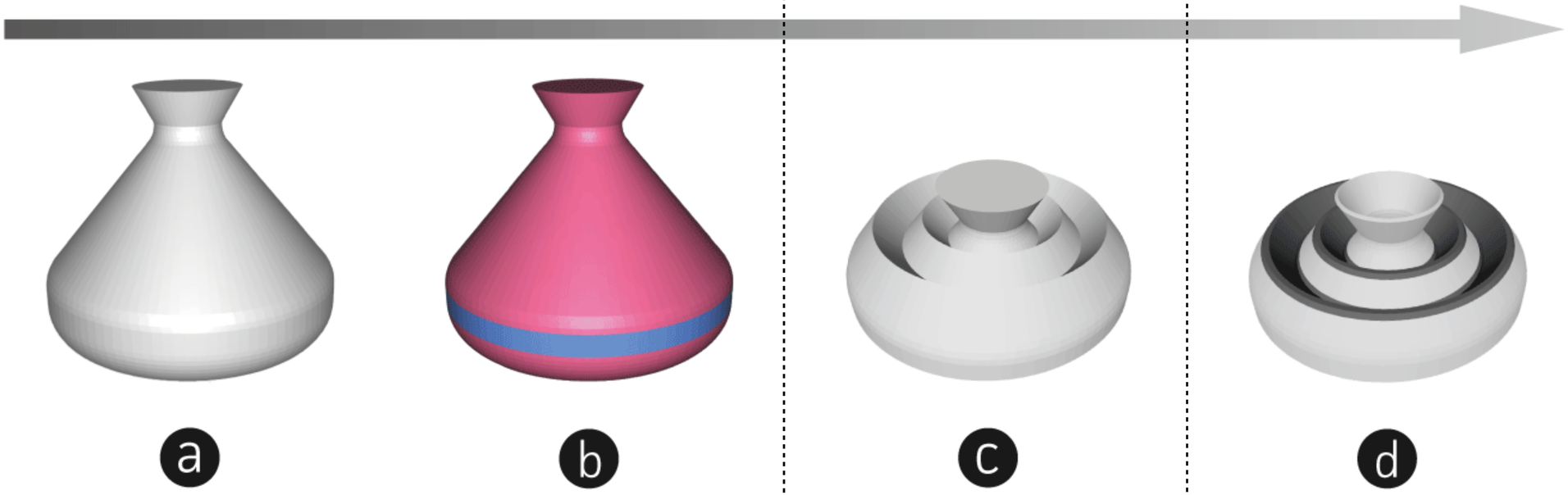
POP-UP PRINT

Rapidly 3D Printing Mechanically Reversible Objects in the Folded State

Yuta Noma, Koya Narumi, Fuminori Okuya, Yoshihiro Kawahara

The University of Tokyo

Overview



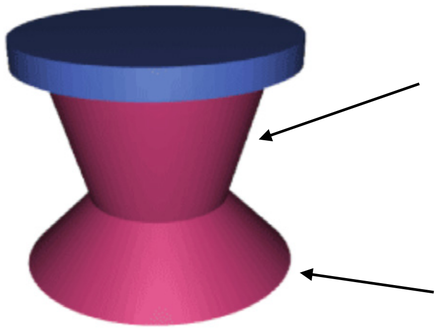
STLを入力すると
システムは**折りたためる部分を可視化**する

モデルを**たたむ**

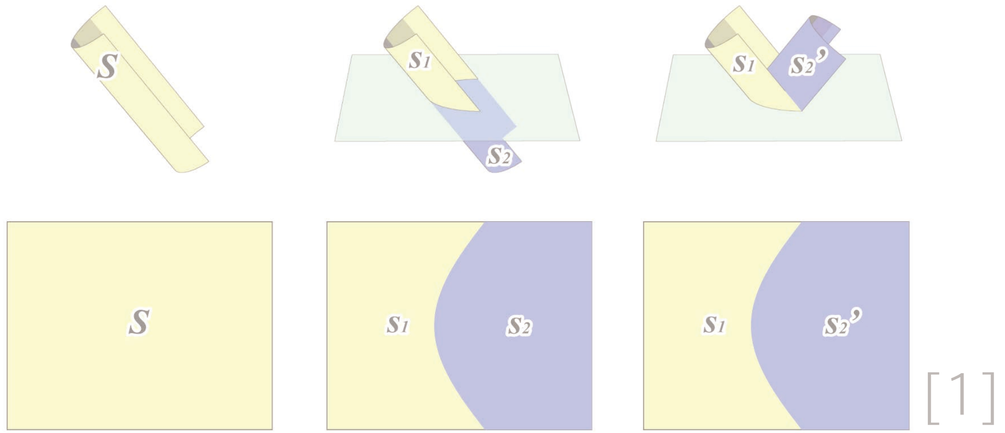
厚み付けし、
硬軟の素材を割り当てる

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

Pop-up Printのたたみ方



① **先細り形状**を探す

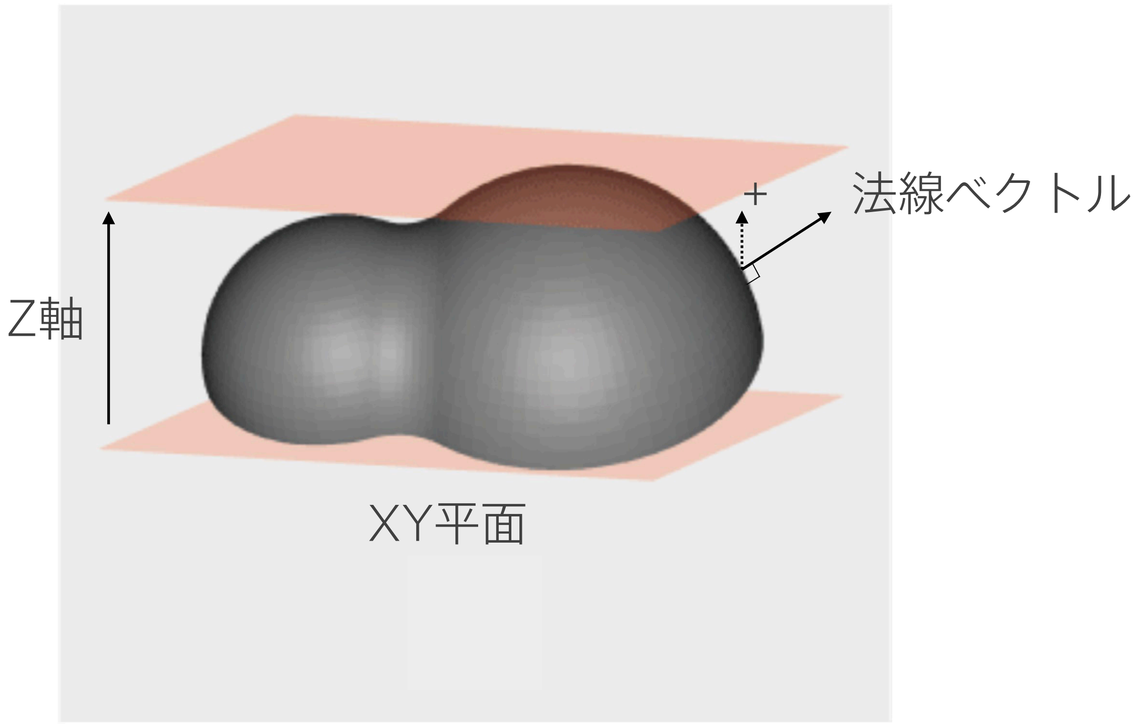


[1]

② 先細り形状に**平坦折り**を適用する

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

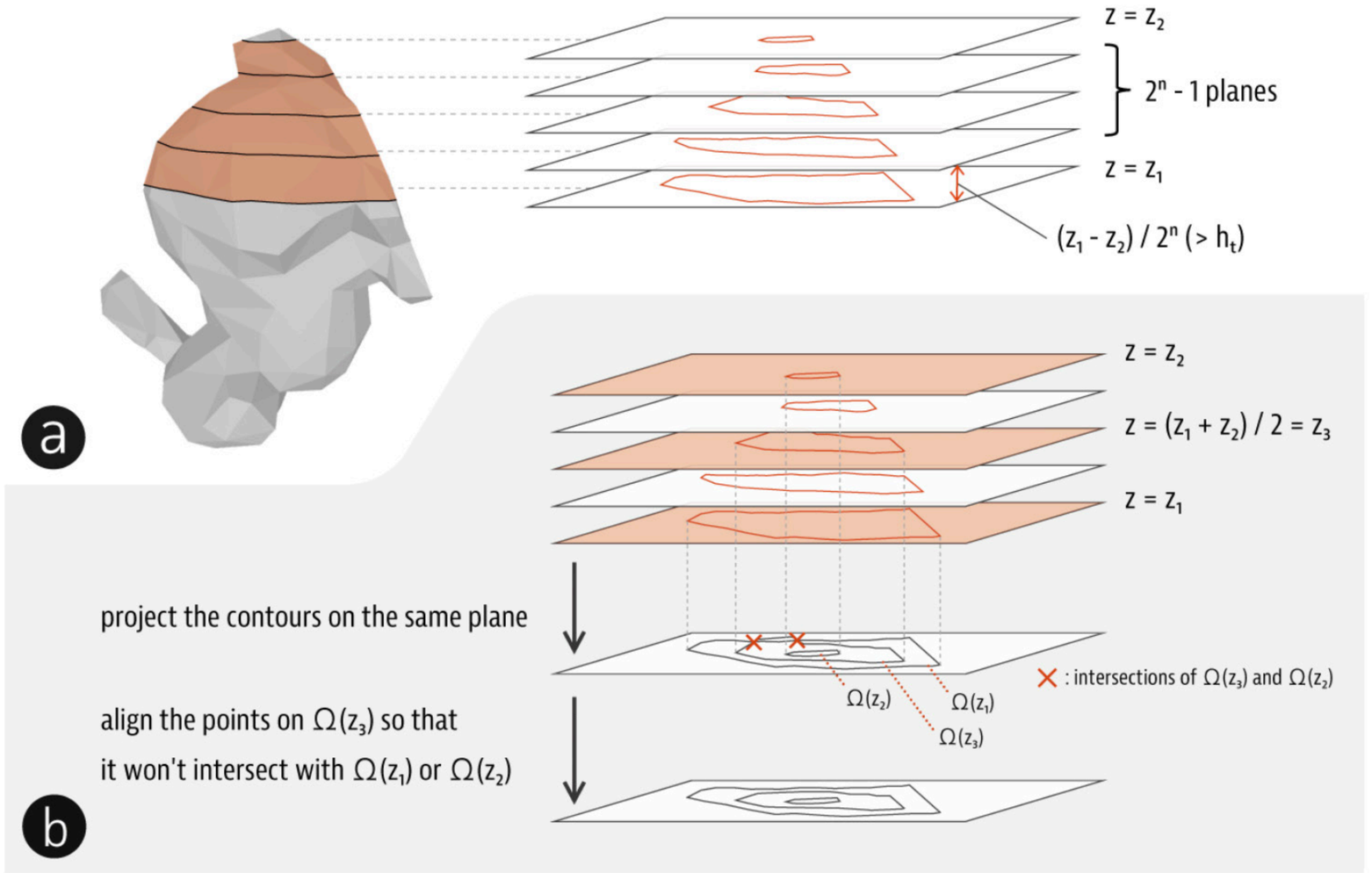
① 先細り形状を探す



すべての領域で法線ベクトルのZ軸方向が同符号 ⇔ 曲面は先細り形状 [2]

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

先細り形状の拡張



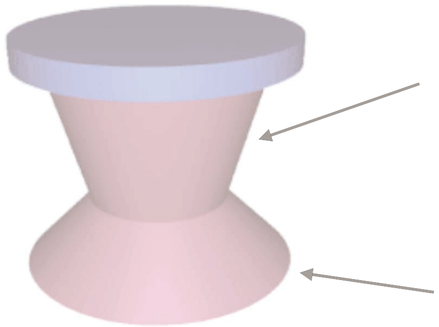
現実問題として、入力形状の多くは
あまり先細っていない

↓

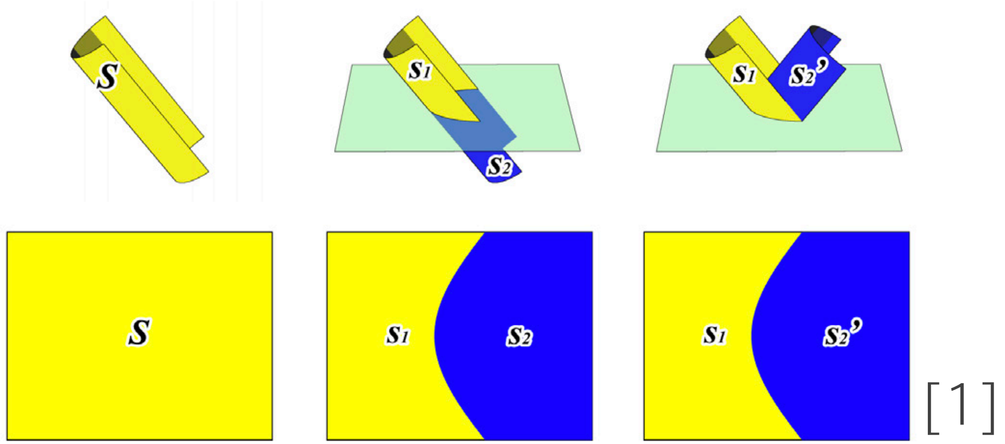
メッシュ構造を少しだけ修正して
先細り部分を拡張

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

Pop-up Printのたたみ方



① **先細り形状**を探す



[1]

② 先細り形状に**平坦折り**を適用する

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

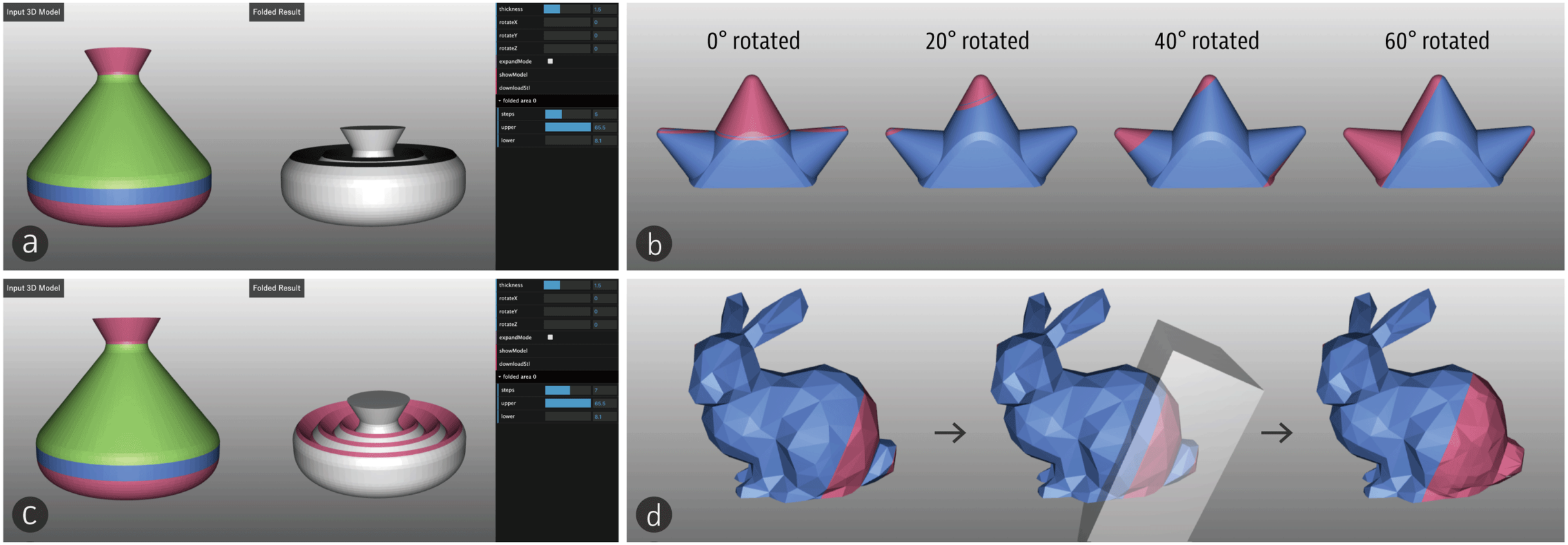
構造の双安定性

悪い例：たたんで印刷したけど双安定じゃない

たたんで印刷した構造を展開するためには、機械的に**双安定 (Bistable)** である必要がある

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

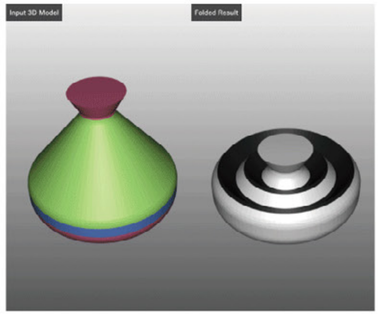
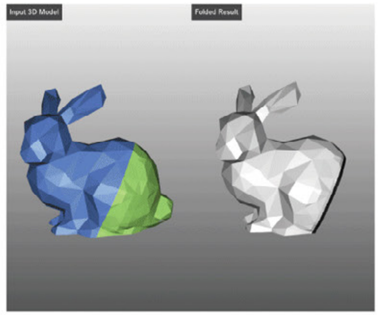
インタラクティブなソフトウェア



たためる場所は赤、**すでにたたまれている場所**は緑、**たためない場所**は青で可視化
ユーザはたたみたい領域をドラッグすることで**先細り形状を拡張できる**

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

Pop-up Printの性能評価

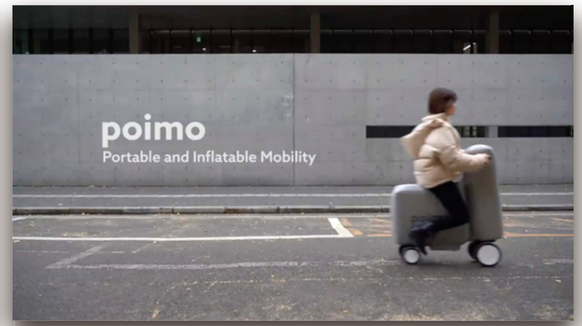
name	properties *1	view of design tool	printed objects
Tokkuri (& Choko)	*without folding* print time: 10 h 24 min support: 477 g *folded* print time: 5 h 20 min support: 342 g		
Stanford Bunny	*without folding* print time: 7 h 16 min support: 149 g *folded* print time: 5 h 25 min support: 141 g		

もっともうまく行った場合、**印刷時間とサポート材消費は1/5まで減少**
邪魔なときは**たたんで収納できる**

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

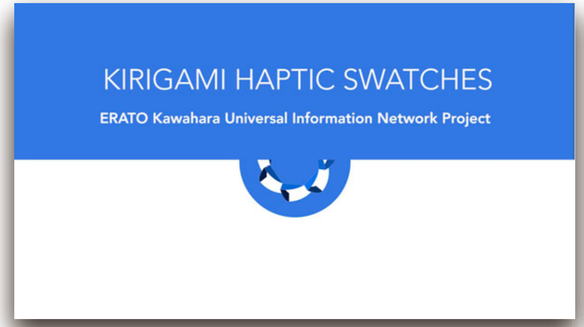
Liquid Pouch Motors
ICRA2017 + RoboSoft2020

Self-healing UI
UIST2019



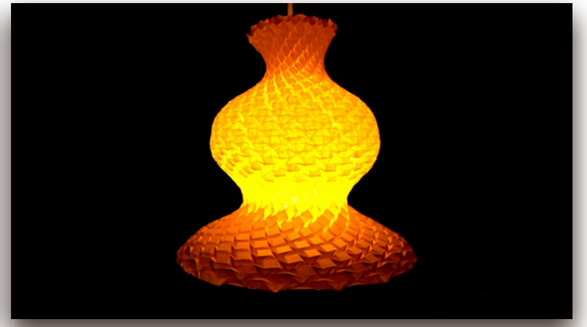
poimo
CHI EA 2020 & UIST2020

Pop-up Print
UIST2020



Kirigami Haptic Swatches
CHI2020

Flower Jelly Printer
CHI2021

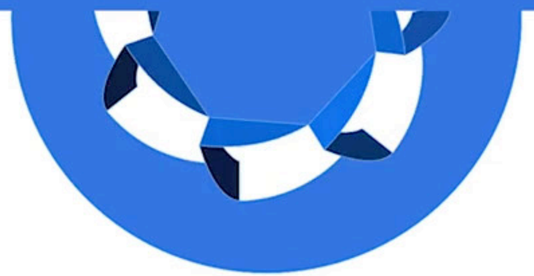


Crane
TOCHI (CHI2023)

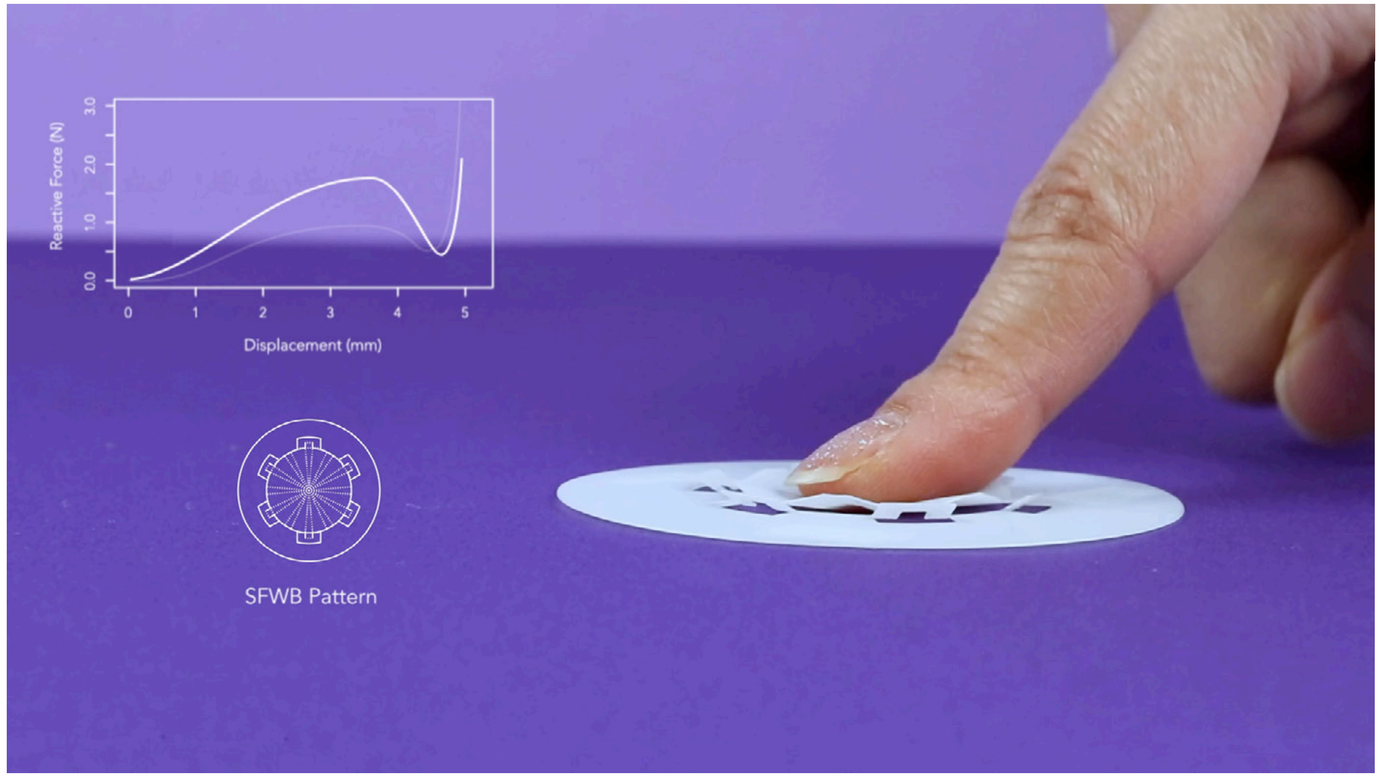
Inkjet 4D Print
TOG (SIGGRAPH2023)

KIRIGAMI HAPTIC SWATCHES

ERATO Kawahara Universal Information Network Project



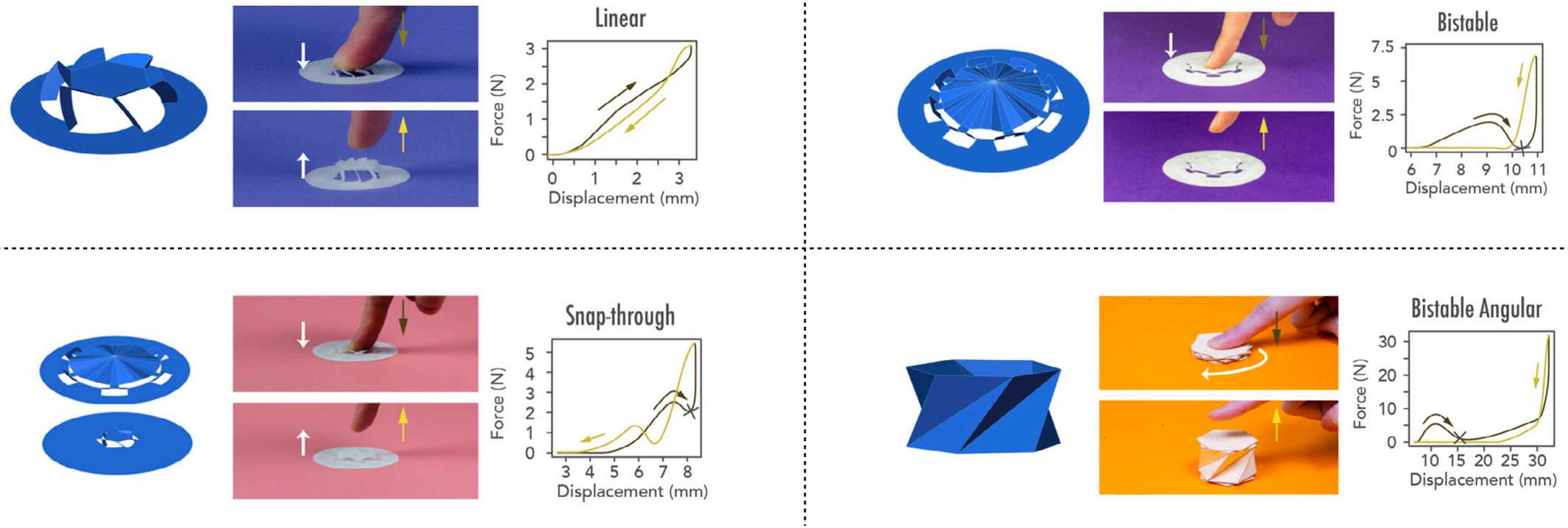
Kirigami Haptic Swatches



切り紙による自分だけの押しボタンの計算設計・計算製造ツール

Chang et al., Kirigami Haptic Swatch, CHI2020

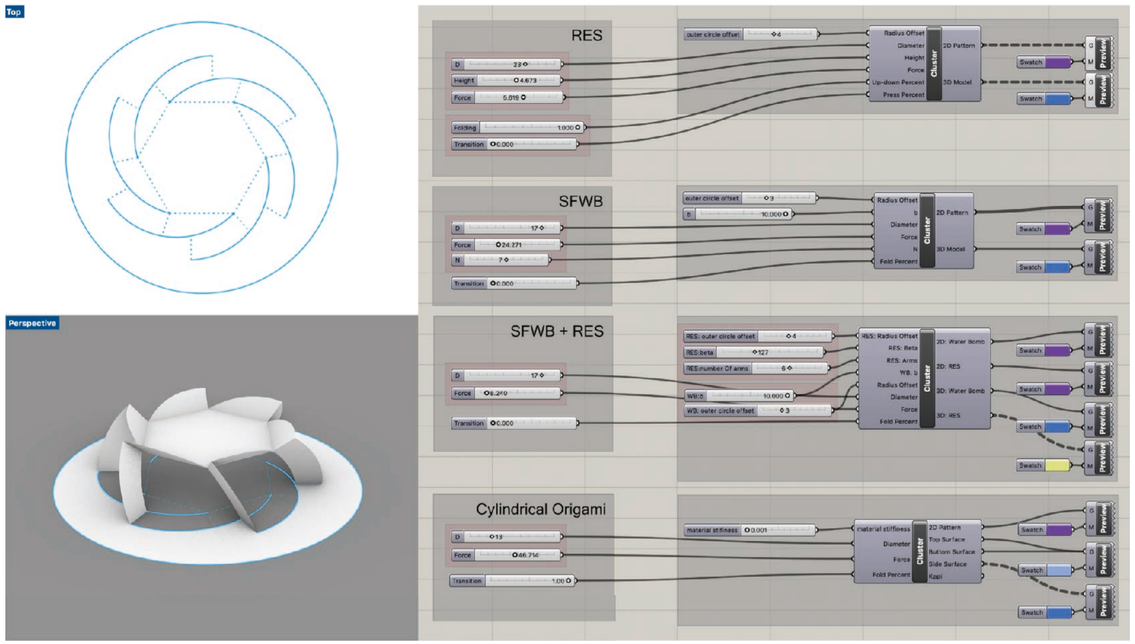
Kirigami Haptic Swatches

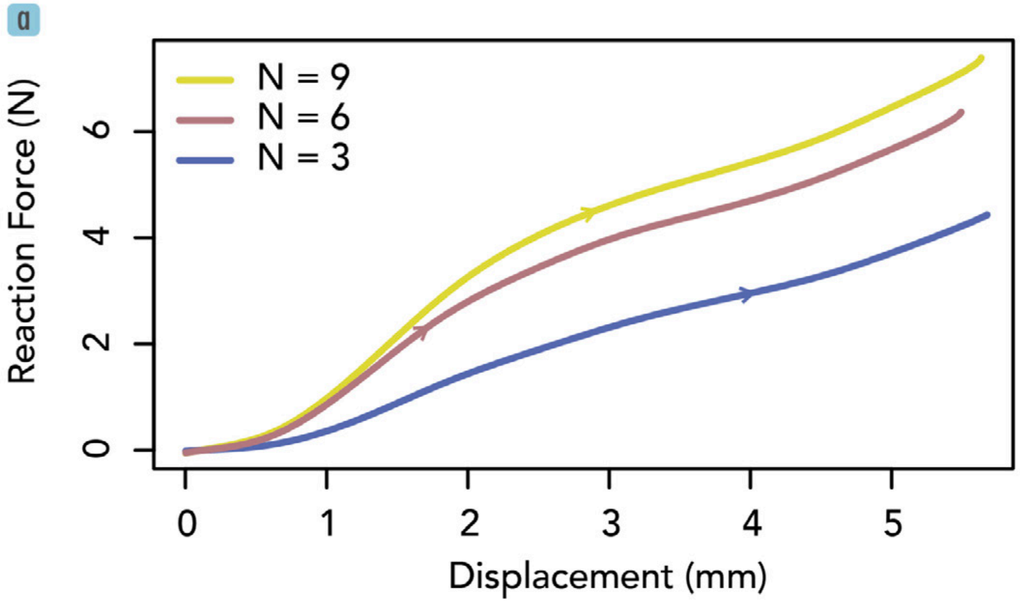


切り紙構造に見られる異なる機械特性を利用し、異なる押し心地を実現可能

Chang et al., Kirigami Haptic Swatch, CHI2020

Kirigami Haptic Swatches





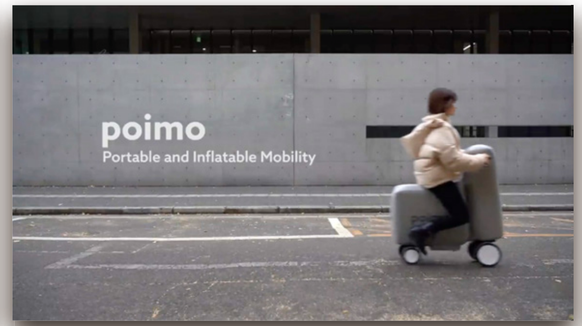
GUIにより異なる形状と機械特性をもつボタンを設計可能

2次元形状なので、**レーザーカッターやカッティングプロッタなどで簡単に作れる**

Chang et al., Kirigami Haptic Swatch, CHI2020

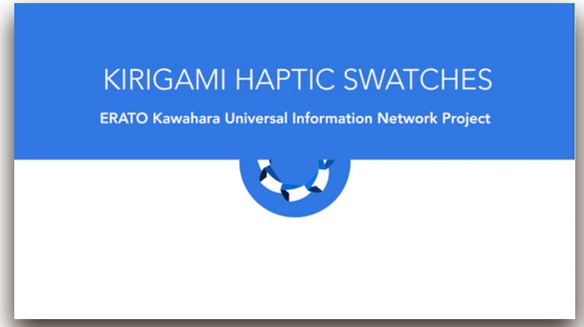
Liquid Pouch Motors
ICRA2017 + RoboSoft2020

Self-healing UI
UIST2019



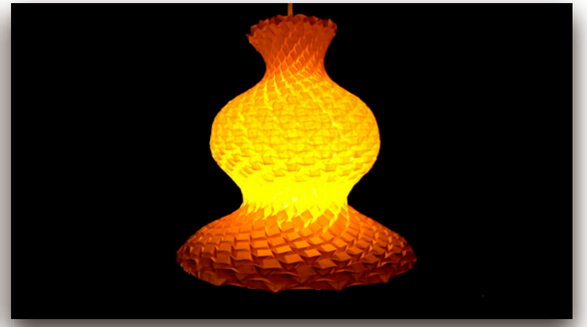
poimo
CHI EA 2020 & UIST2020

Pop-up Print
UIST2020



Kirigami Haptic Swatches
CHI2020

Flower Jelly Printer
CHI2021



Crane
TOCHI (CHI2023)

Inkjet 4D Print
TOG (SIGGRAPH2023)


Flower Jelly Printer

Flower Jelly Printer

フラワーゼリーというパティシエ手作りの複雑なゼリーの計算設計・製造ツール

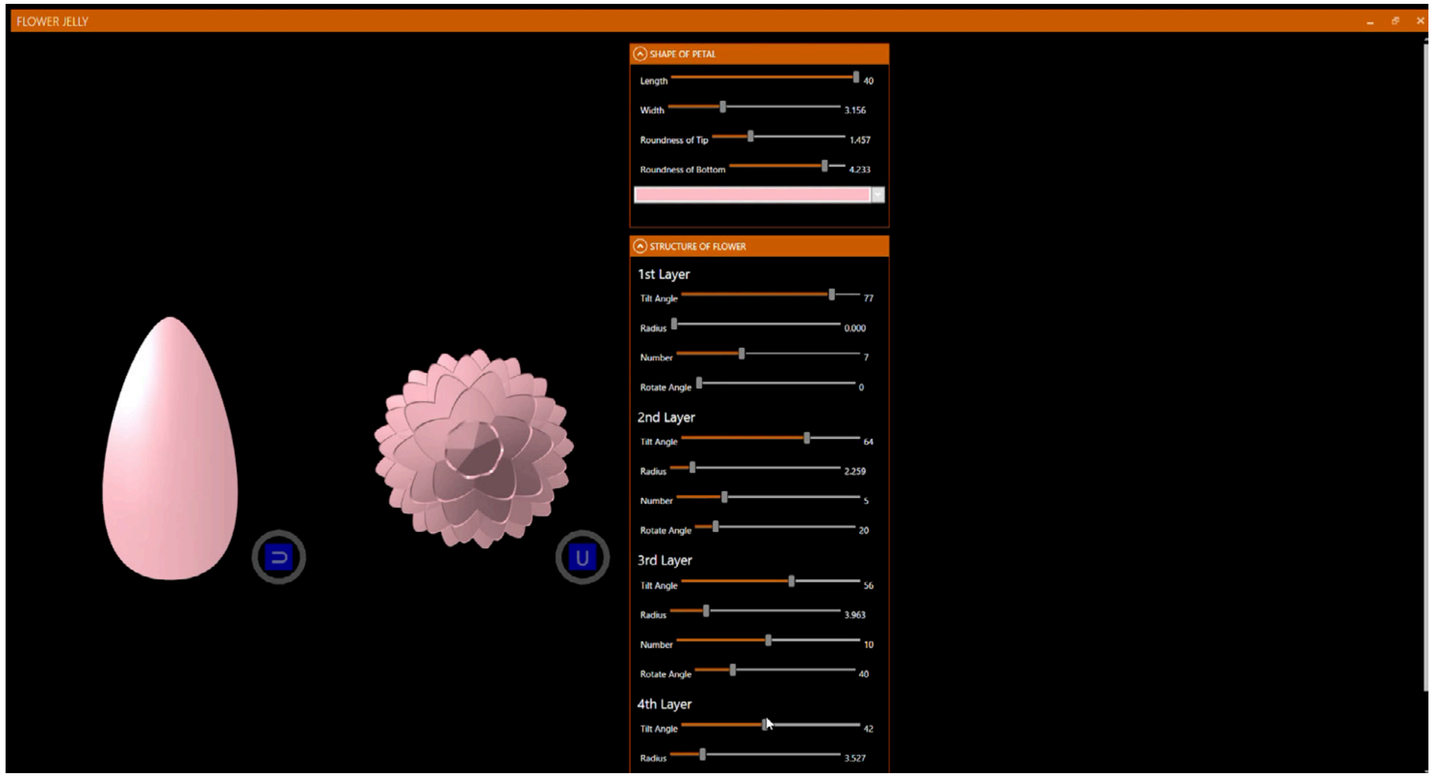
Miyatake et al., Flower Jelly Printer, CHI2021

従来のフラワーゼリー作製

パティシエや経験者の**集中力**と**時間**が必要で、一発勝負
作製後に**ひっくり返して完成**となるため、最終形状の予測が難しい

Miyatake et al., Flower Jelly Printer, CHI2021

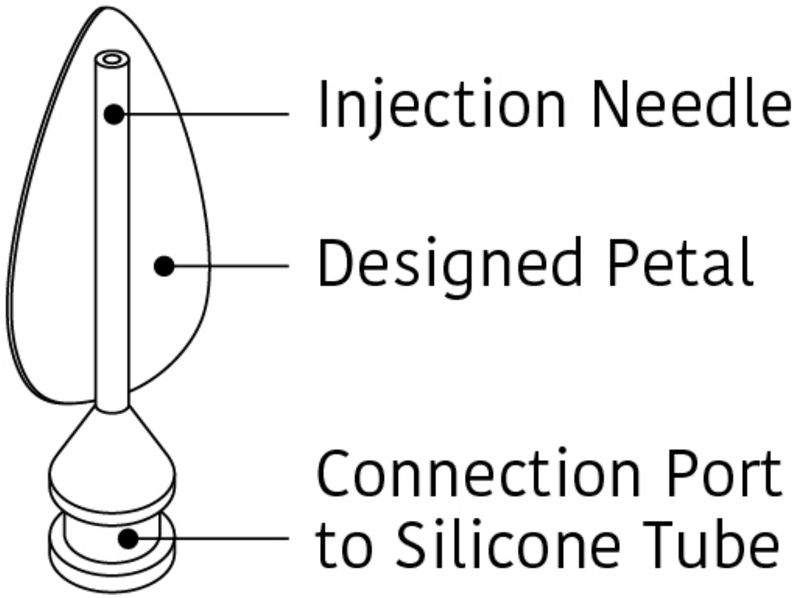
設計ソフトウェア

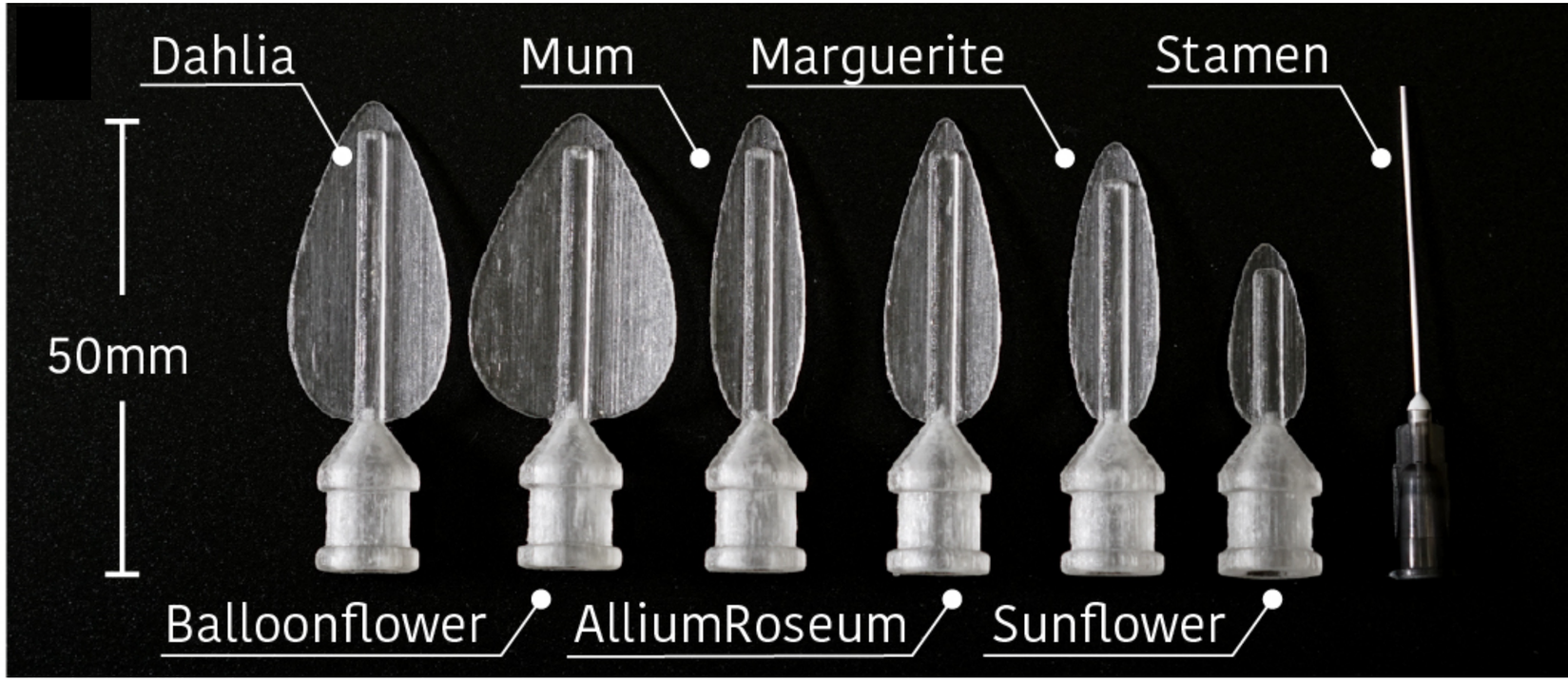


ユーザはGUIにより試行錯誤しながら形状を探索できる
形状が完成すると、GUIは花のSTLファイルとナイフのSTLファイルを出力する

Miyatake et al., Flower Jelly Printer, CHI2021

ナイフの造形

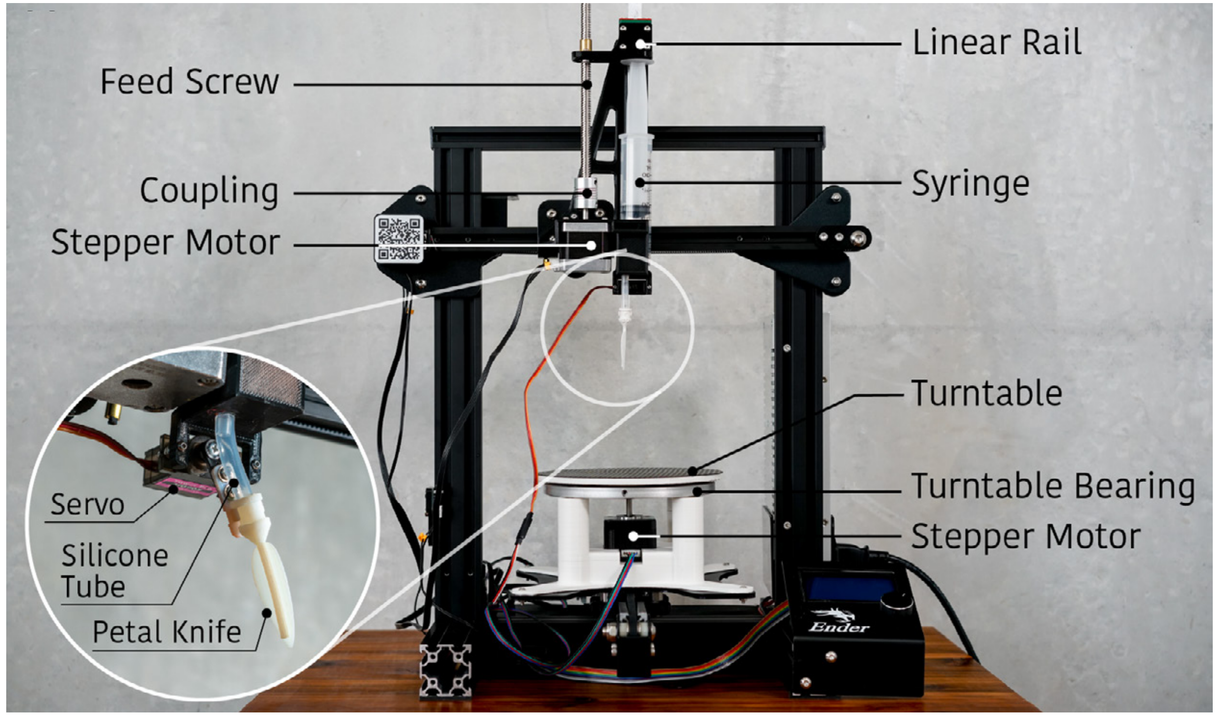


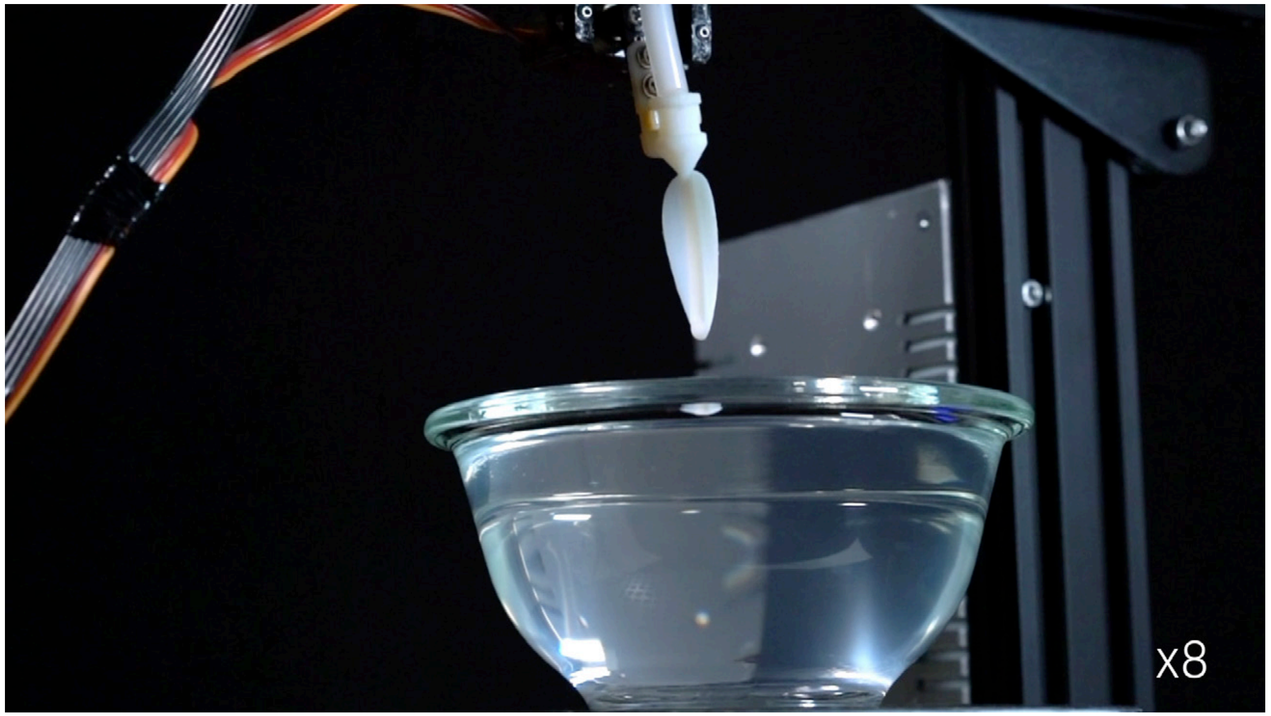


ユーザはGUIにより試行錯誤しながら形状を探索できる
形状が完成すると、GUIは花のSTLファイルとナイフのSTLファイルを出力する

Miyatake et al., Flower Jelly Printer, CHI2021

Slit Injection Printer

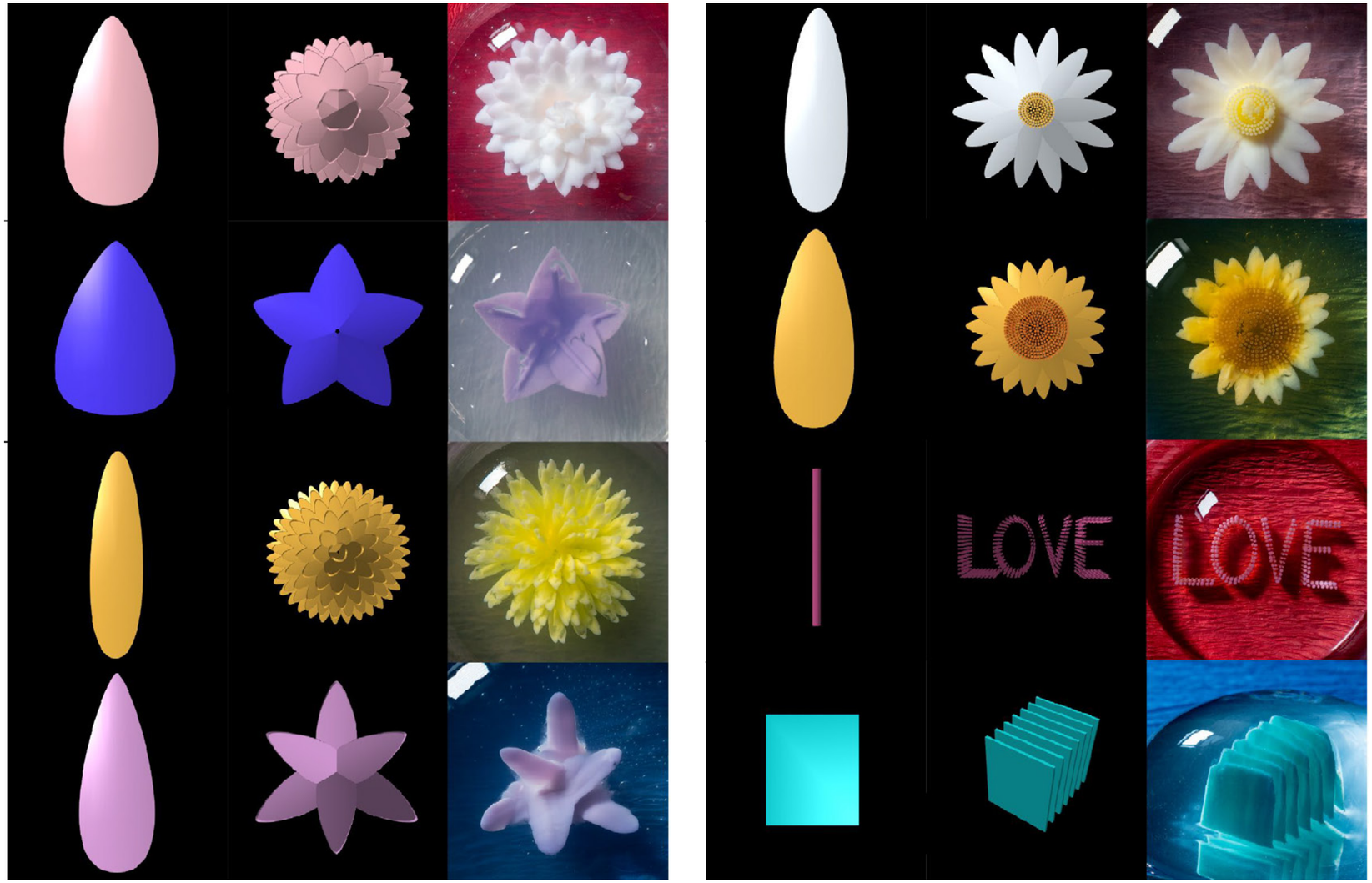




ゼリーの中にゼリーを造形するため、**Slit Injection Printing**という造形方法を確立

Miyatake et al., Flower Jelly Printer, CHI2021

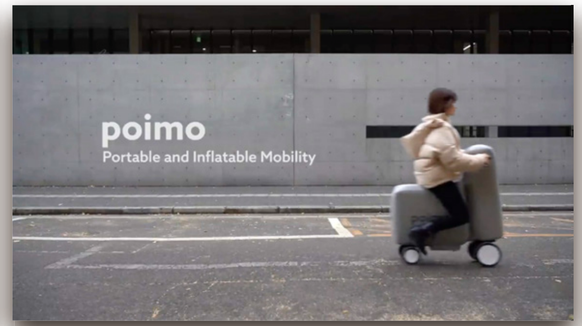
デザイン事例



Miyatake et al., Flower Jelly Printer, CHI2021

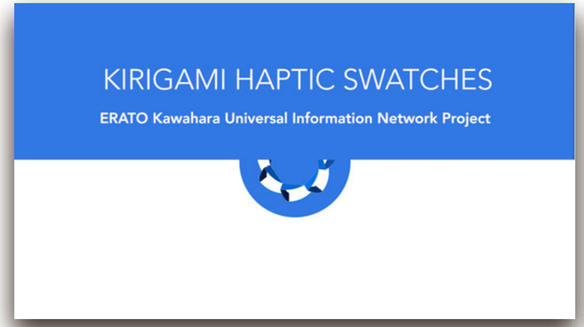
Liquid Pouch Motors
ICRA2017 + RoboSoft2020

Self-healing UI
UIST2019



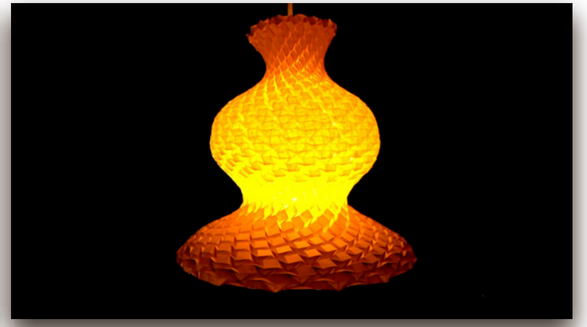
poimo
CHI EA 2020 & UIST2020

Pop-up Print
UIST2020



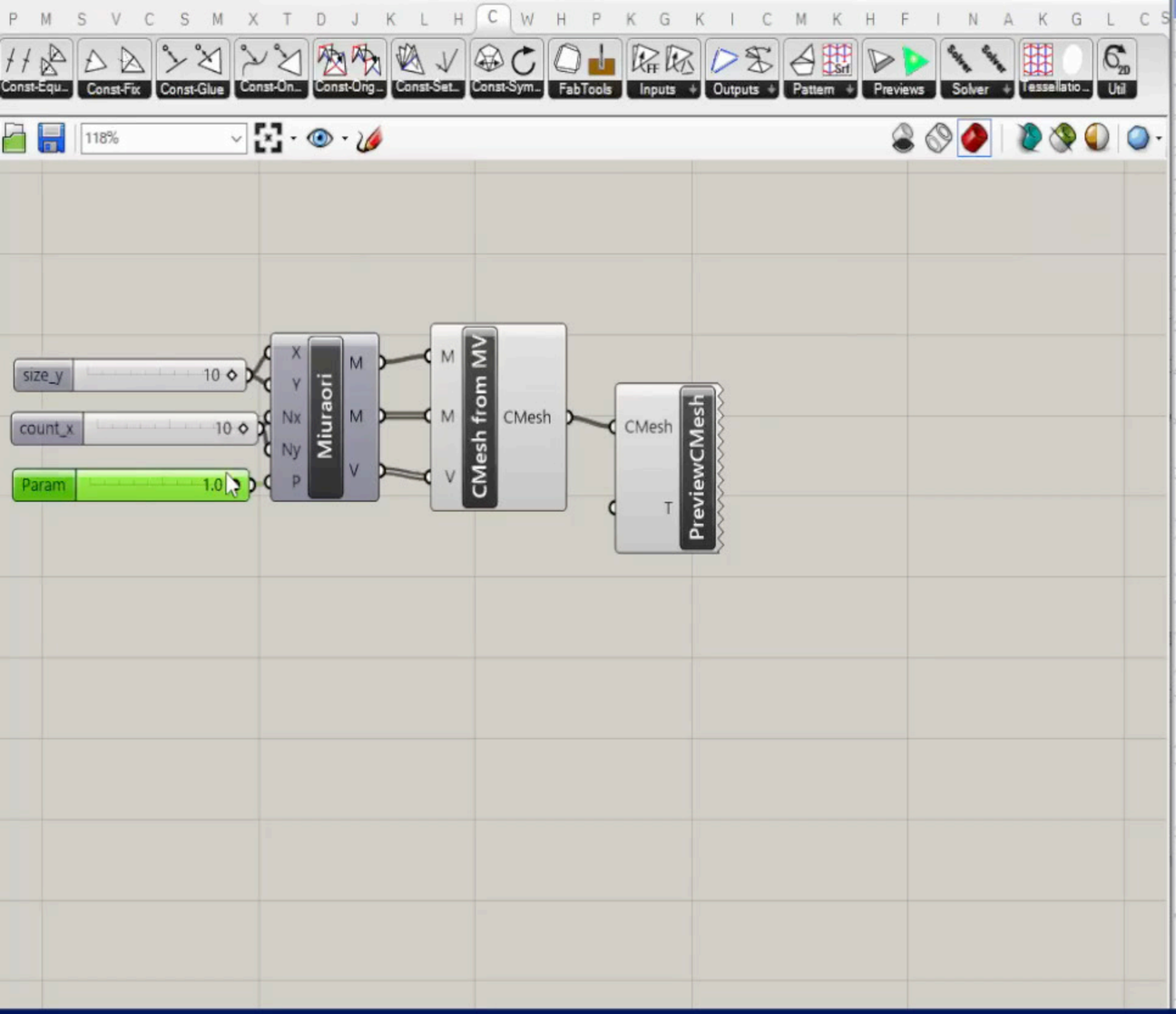
Kirigami Haptic Swatches
CHI2020

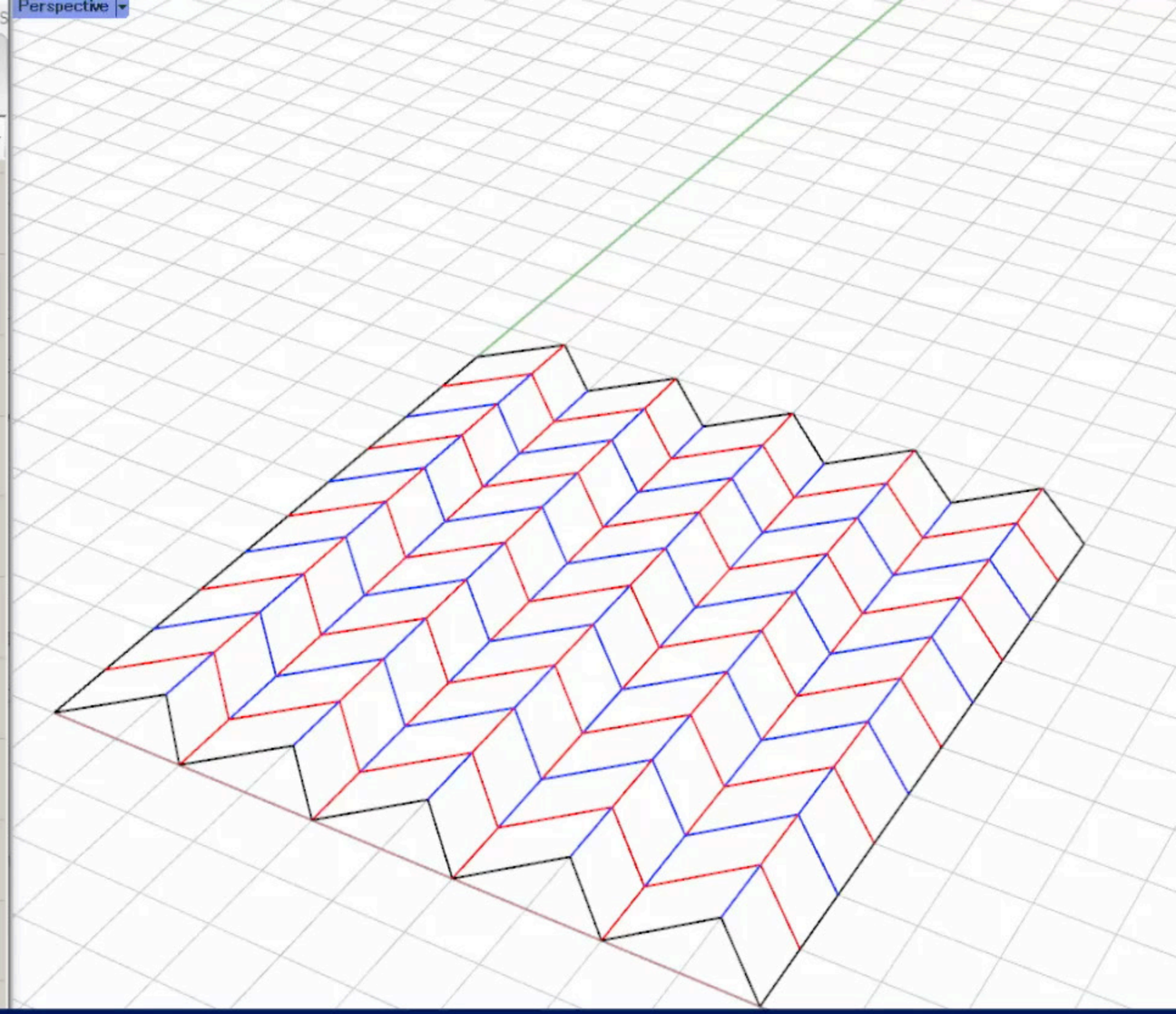
Flower Jelly Printer
CHI2021



Crane
TOCHI (CHI2023)

Inkjet 4D Print
TOG (SIGGRAPH2023)





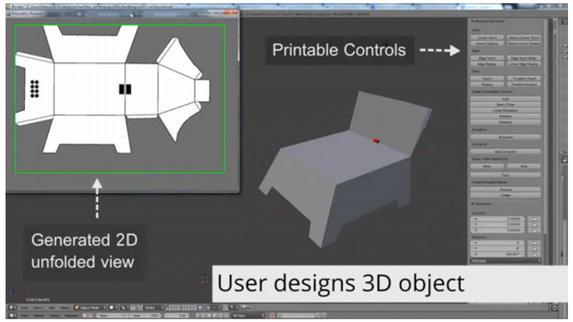
CRANE

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

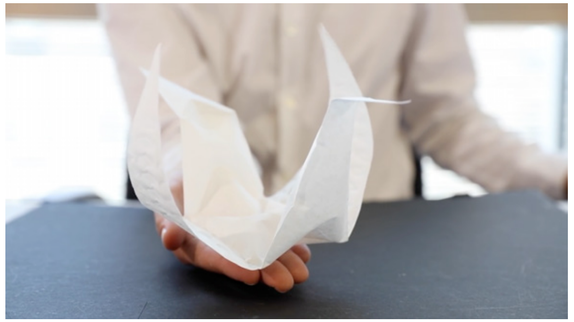
Kai Suto, Yuta Noma, Kotaro Tanimichi, Koya Narumi, Tomohiro Tachi
The University of Tokyo, Nature Architects, Inc.

ファブの研究者は折紙が好き

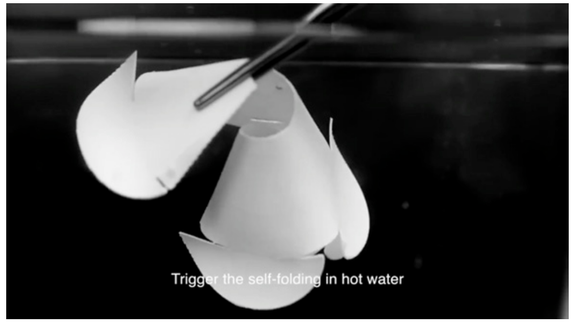
LaserOrigami (CHI'13)



Foldio (UIST'15)



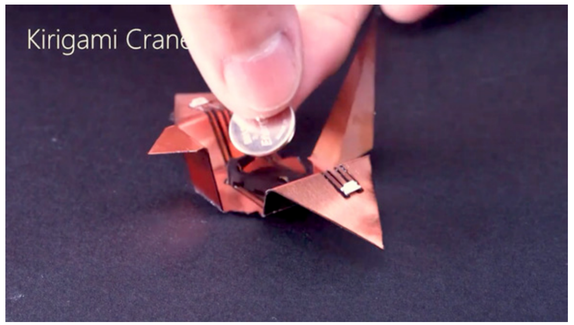
aeroMorph (UIST'16)



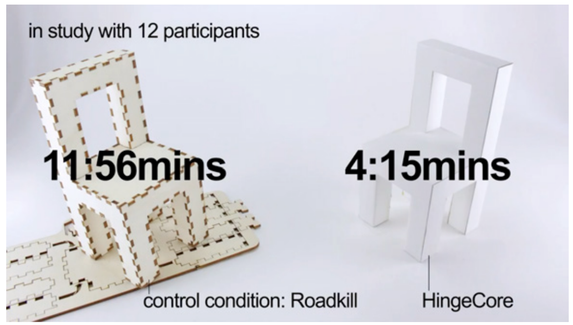
Thermorph (CHI'18)

Kirigami Haptic Swatches (CHI'20)

Flaticulation (UIST'22)

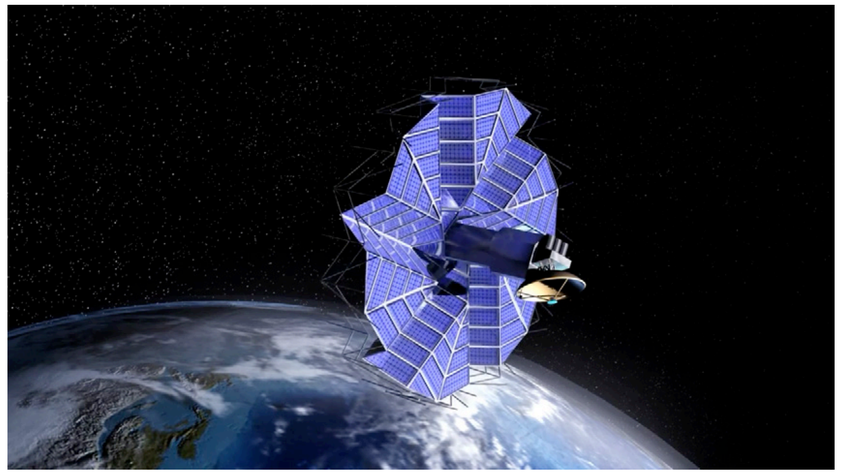


Fibercuit (UIST'22)

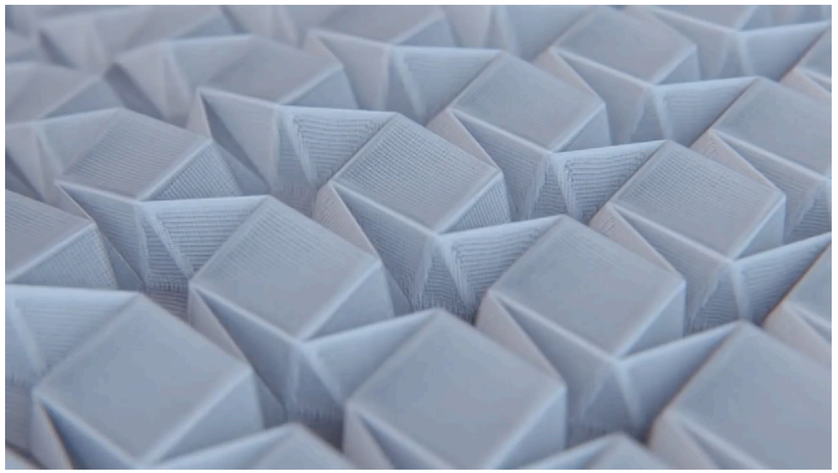


HingeCore (UIST'22)

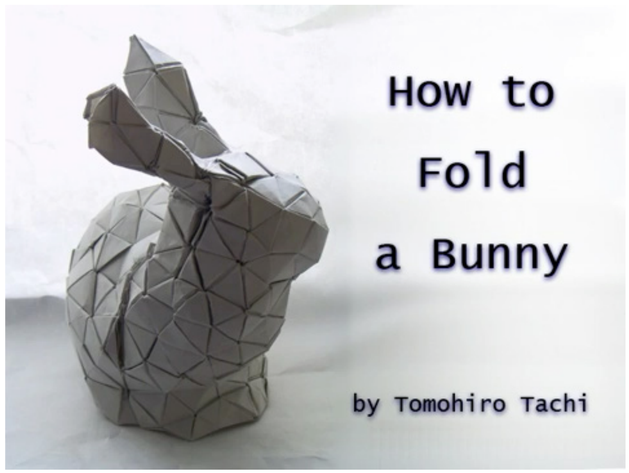
でも折紙はもっと奥が深い



宇宙工学 [1]



衣服 [2]



任意の多面体 [3]

工学・**産業**・**数学**の分野で利用される折紙はファブの人が作る構造より**ずっと複雑**

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

イントロダクション：これって簡単に作れる？

ぱっと見ただけでは、IKEAの「**折りたたみ家具**」とあまり変わらない

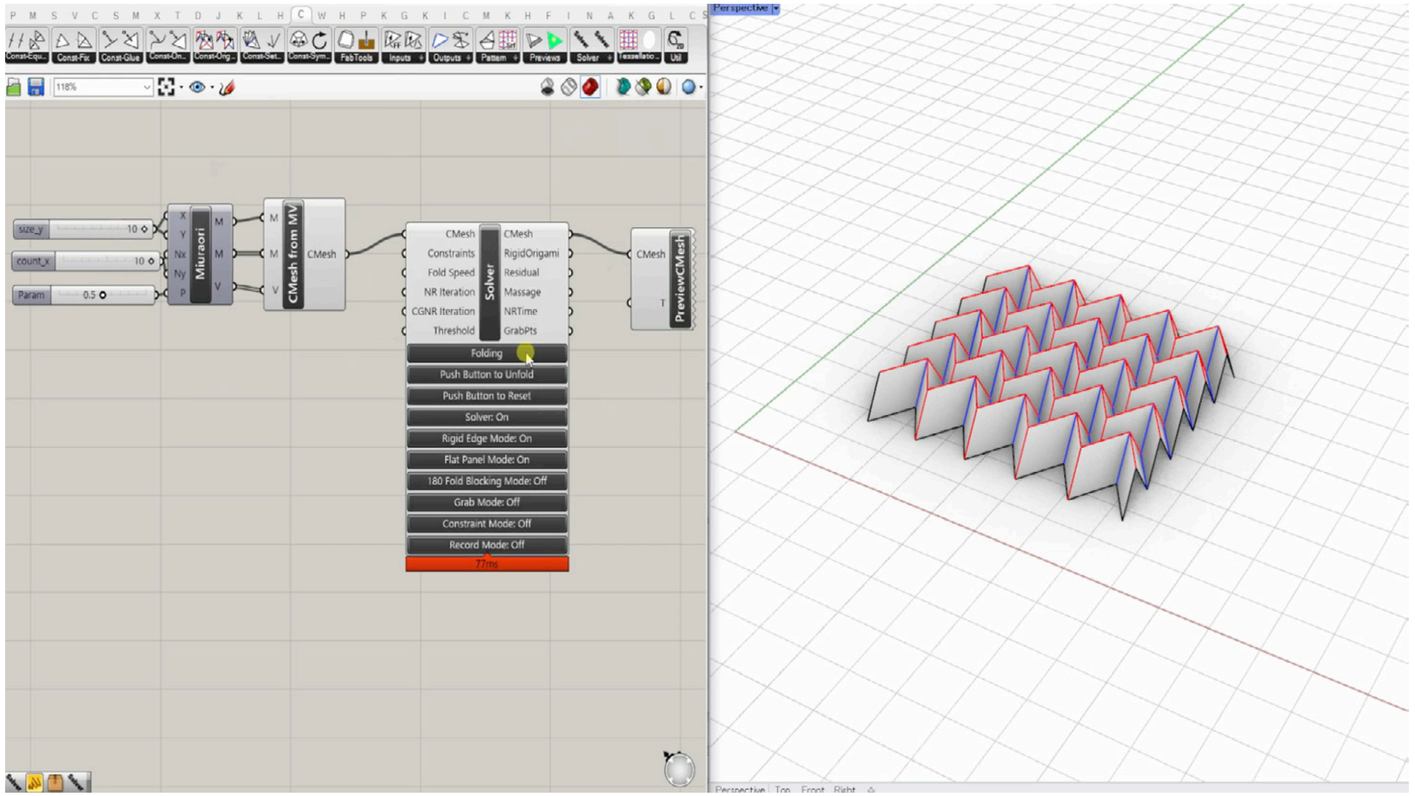
イントロダクション：これって簡単に作れる？

実際には、**折りたたみ家具**と**折紙プロダクト**の難易度はまったく異なる

CRANE

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

CraneのGUI



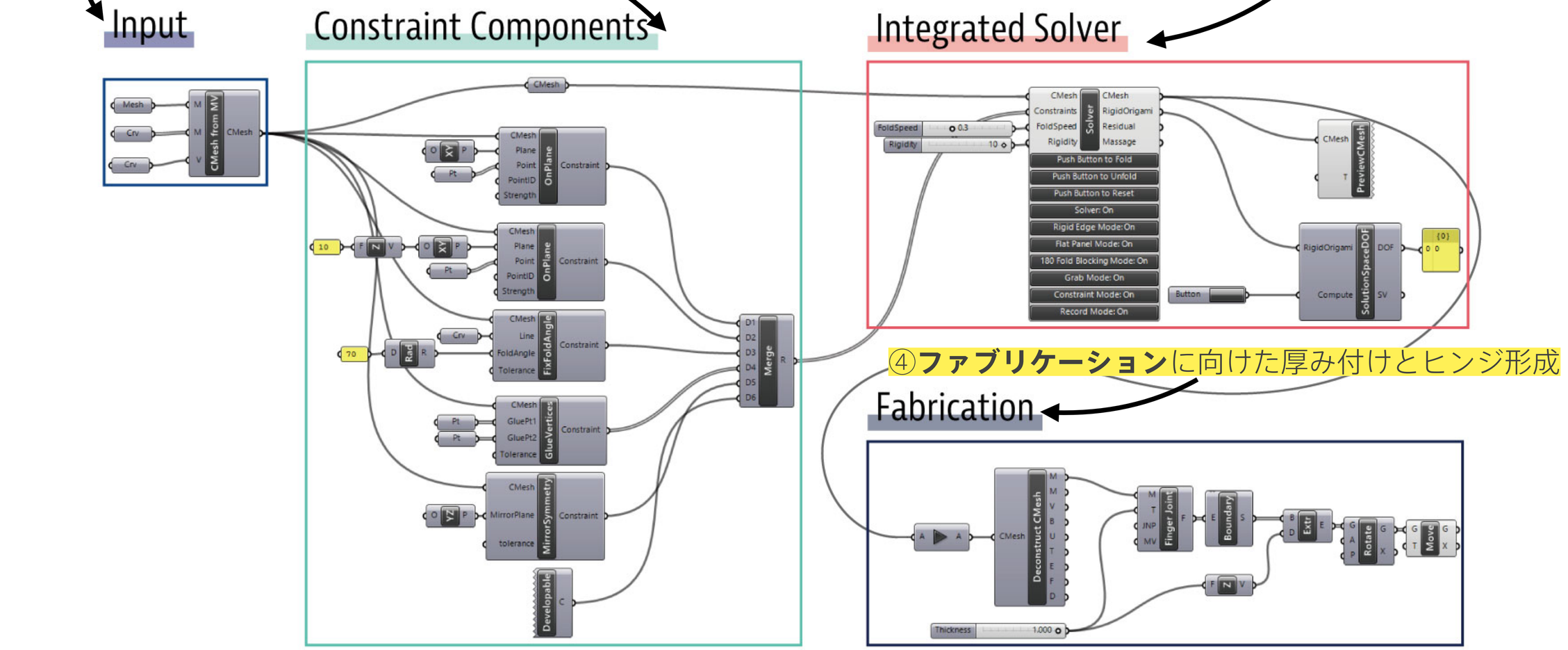
CraneはRhino/Grasshopper上に実装されている
コンポーネントを置くウィンドウとモデルを表示するウィンドウがある

Craneの作業の流れ

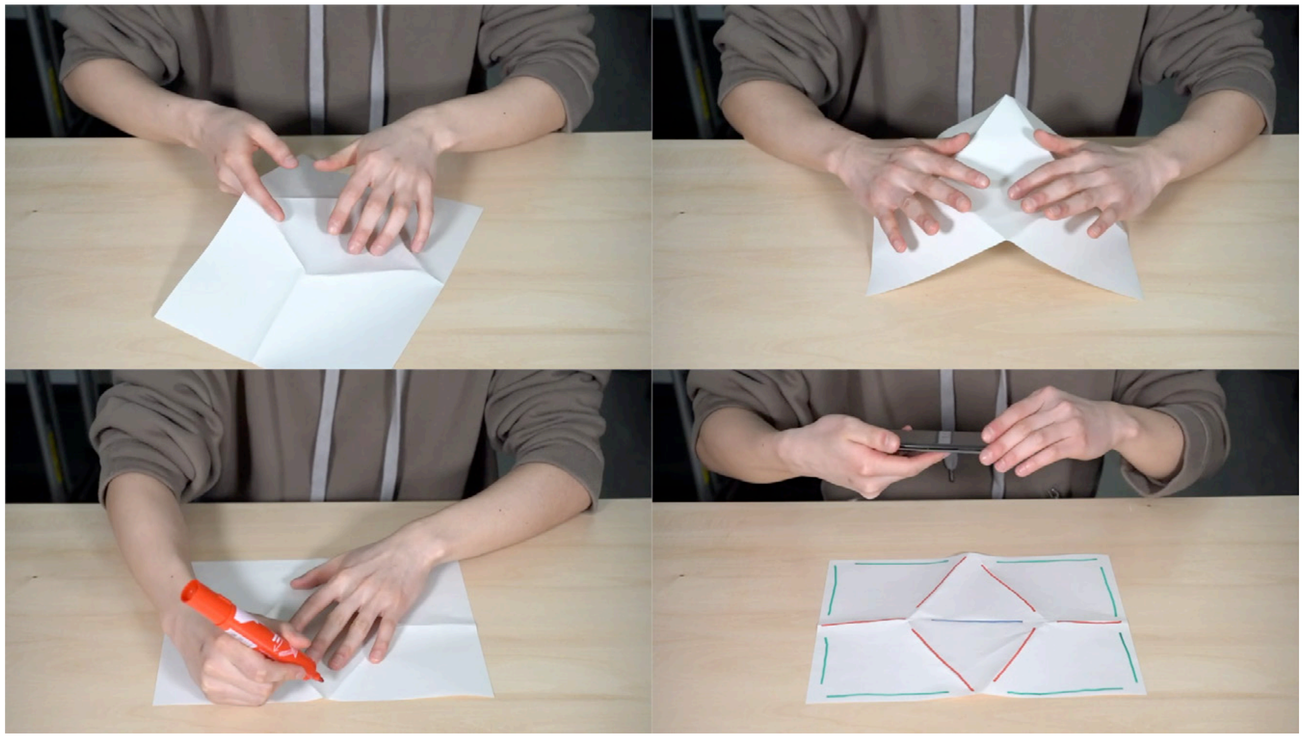
①**入力**を与える

②折紙が満たすべき**制約**を並べる

③シミュレーションと**形状探索**を行う

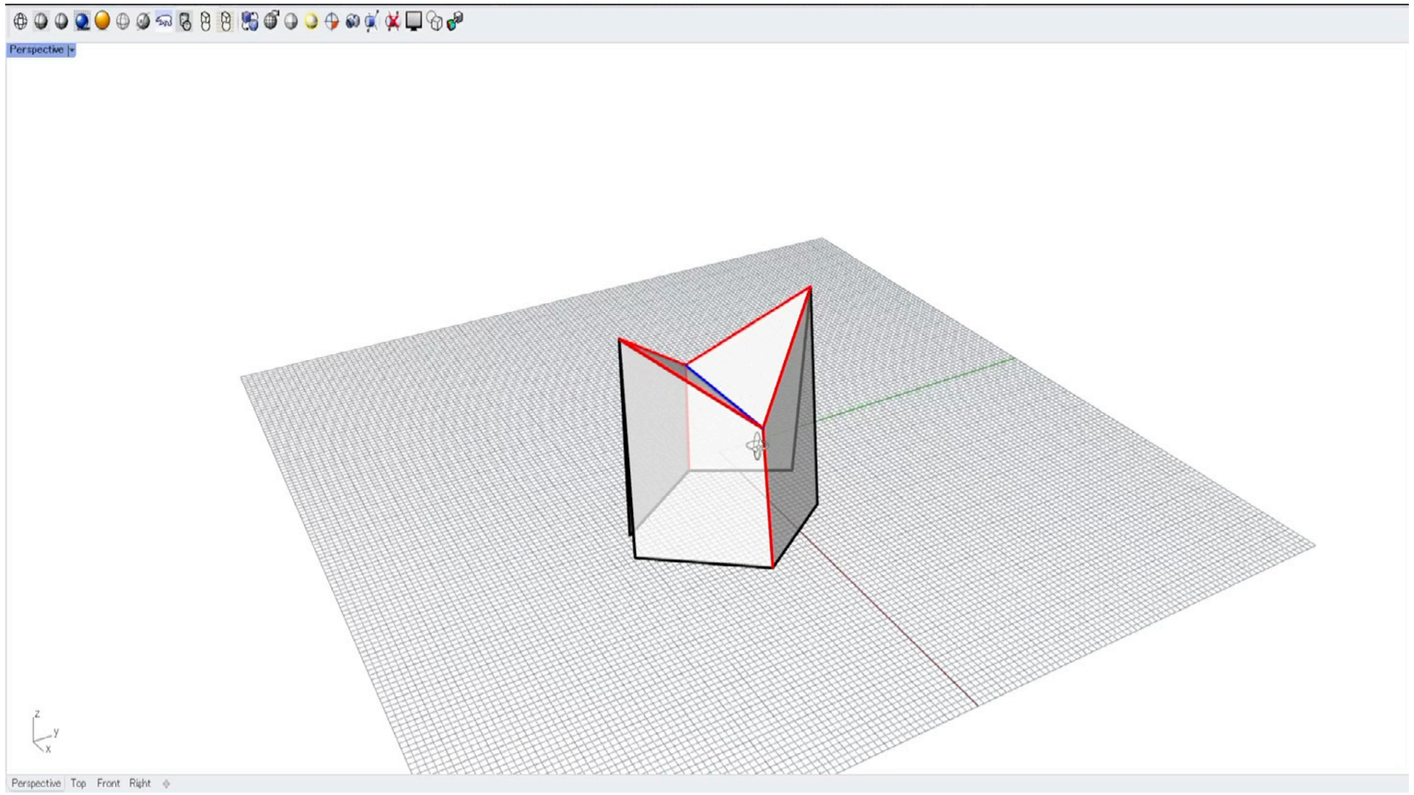


①入力: 手描き



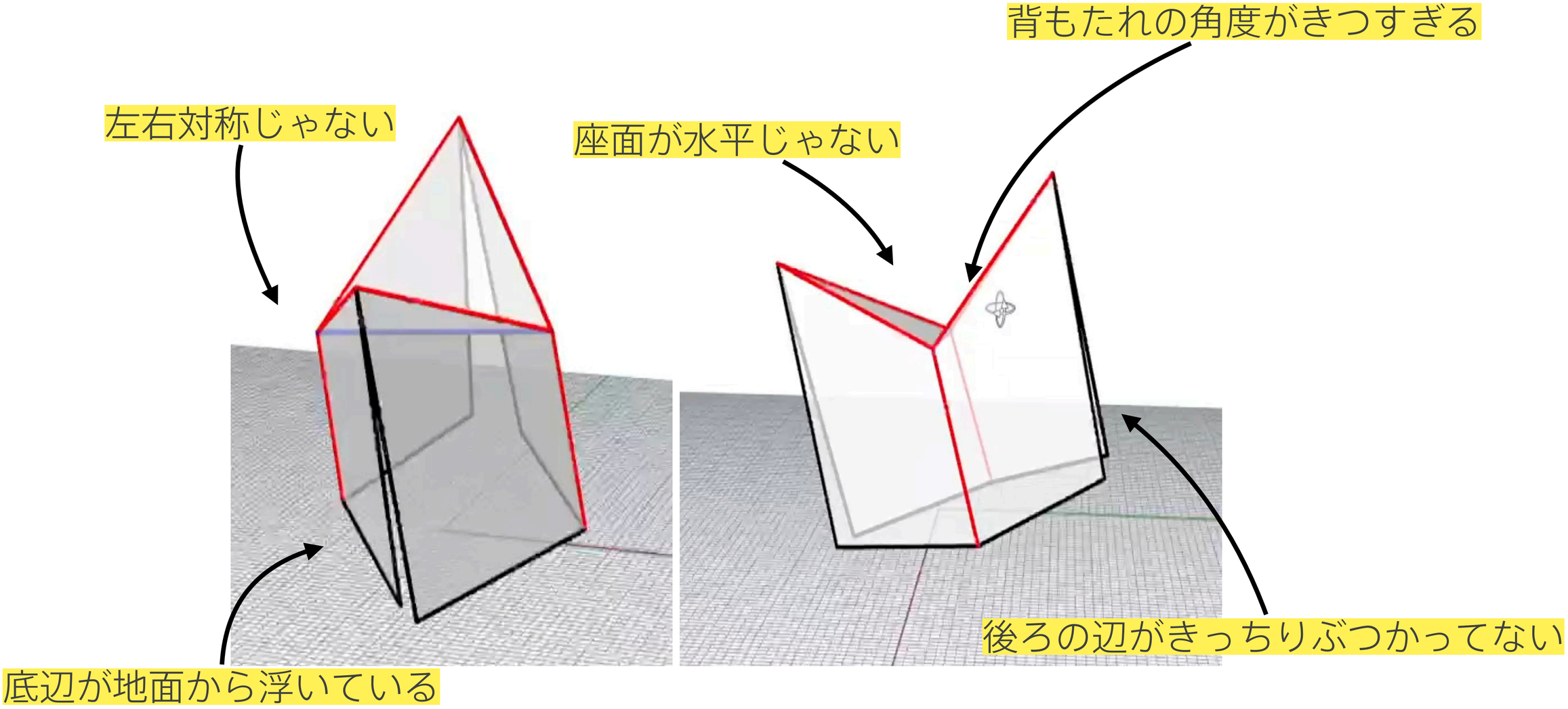
実際に紙で試作を行い、その折線に色（山・谷・境界）をつけて写真を撮る
システムは画像を受け取り、CADで扱えるグラフに変換する

③シミュレーション

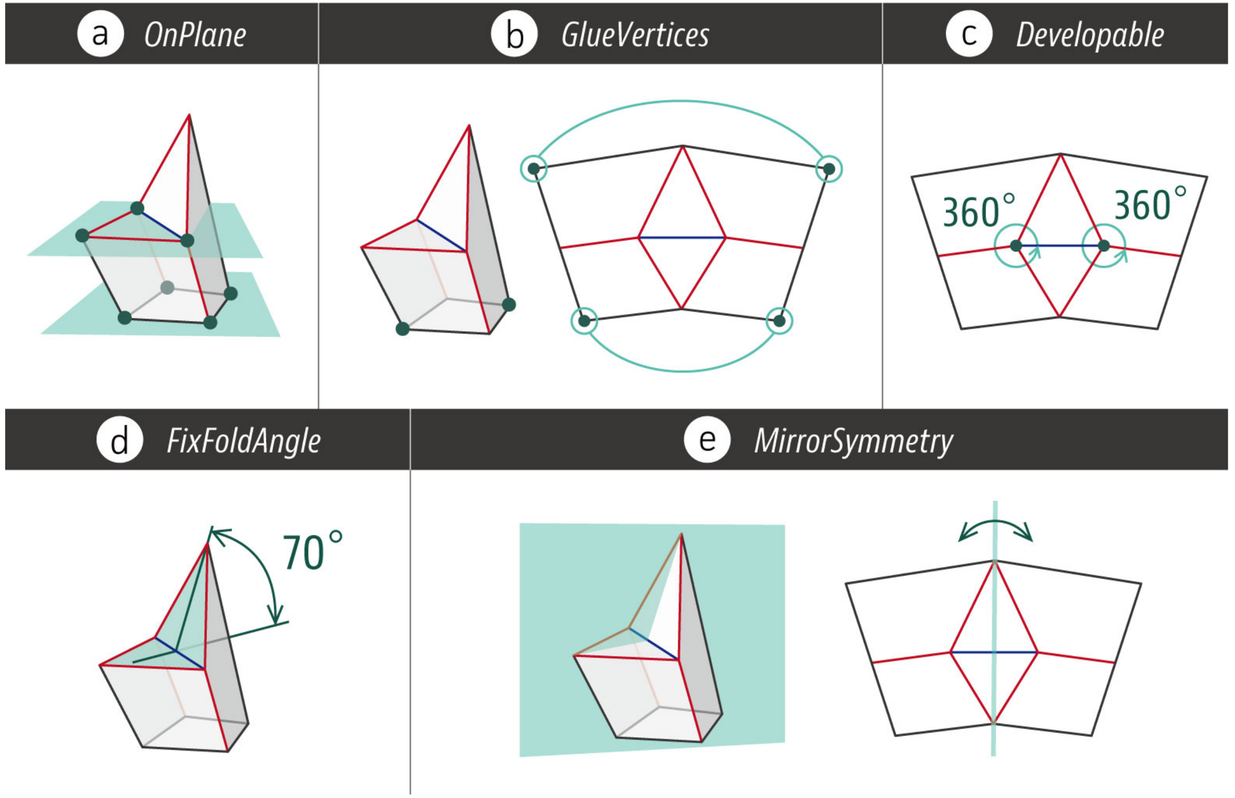


さっき作った椅子の動きをシミュレーションしている
ただ、この椅子は実用的には全然駄目

②制約と③形状探索

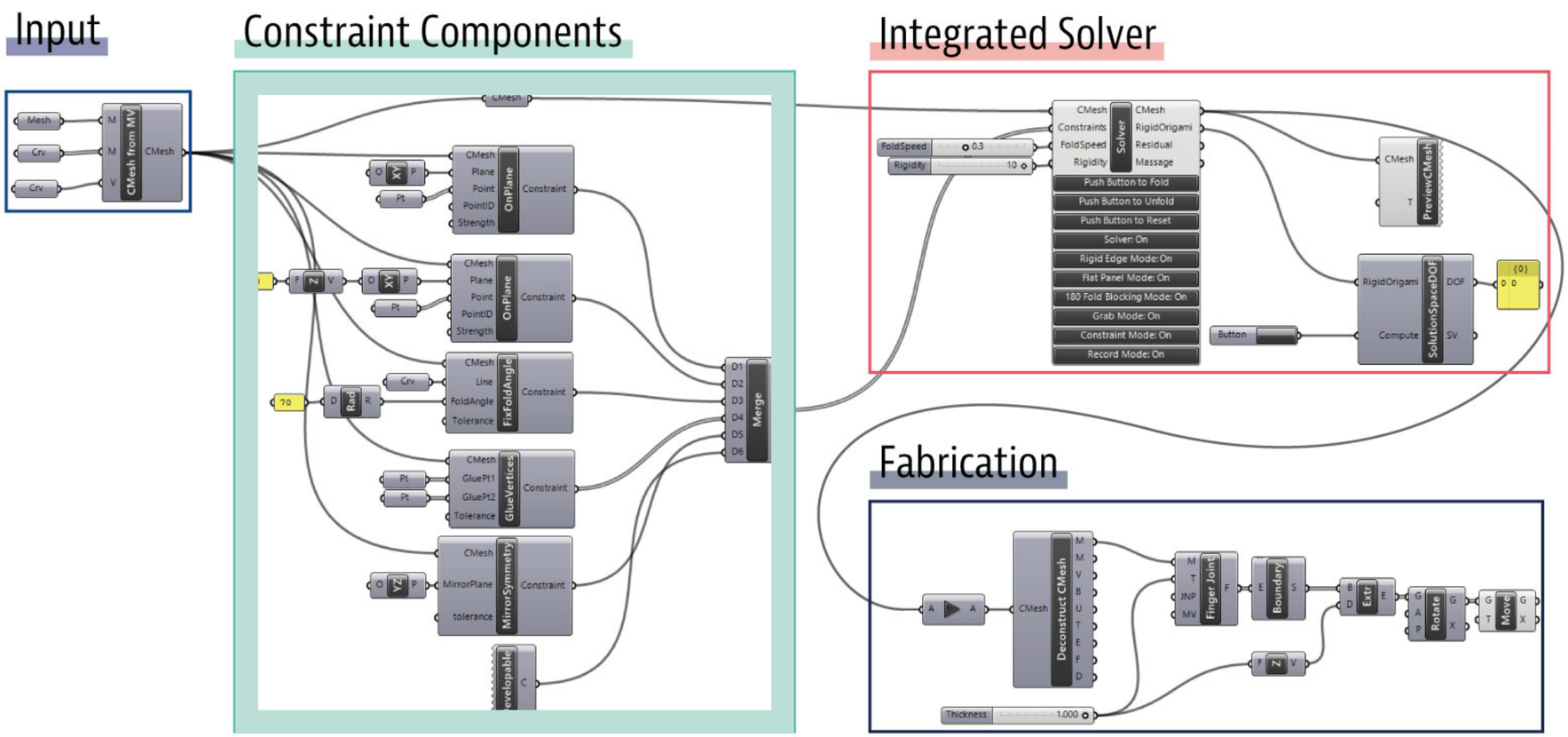

背もたれの角度がきつすぎる
左右対称じゃない
座面が水平じゃない
後ろの辺がきっちりぶつかってない
底辺が地面から浮いている

②制約と③形状探索



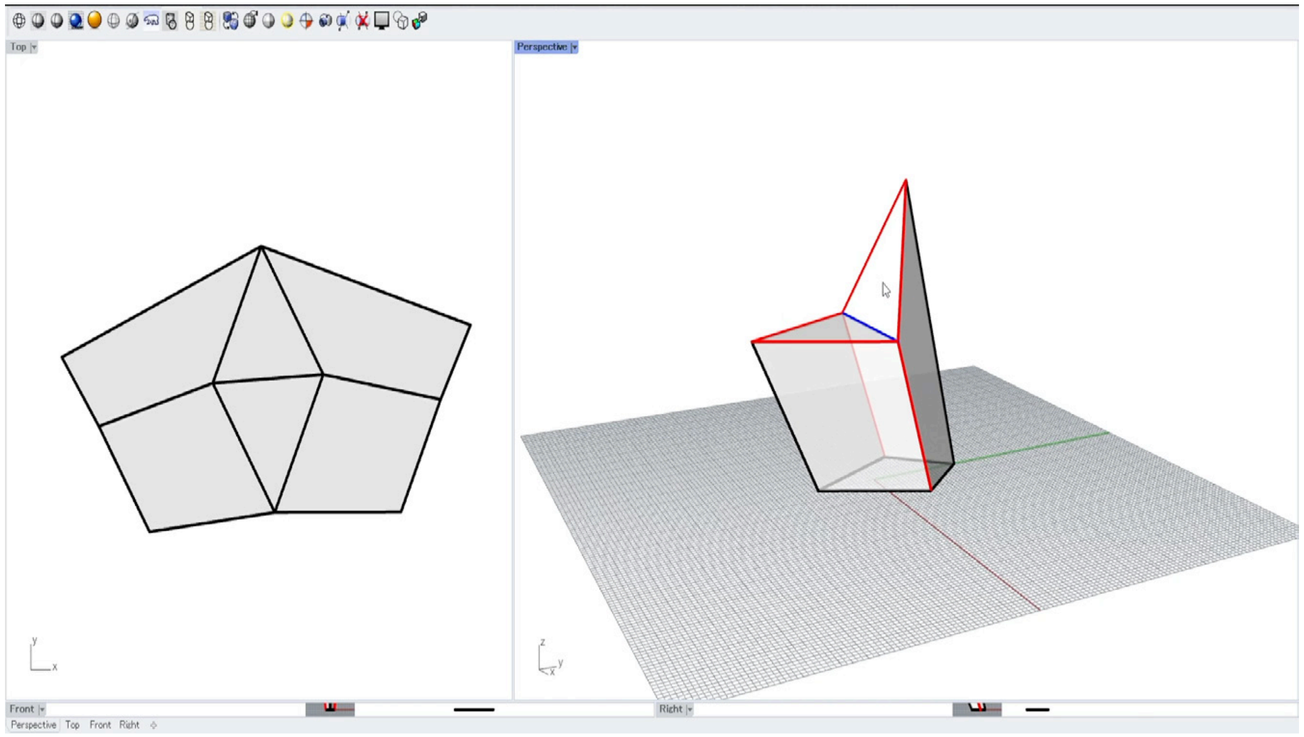
ユーザは**意匠性**と**可折性**を満たす制約を考えて配置する

②制約と③形状探索



制約を並べてソルバーに接続

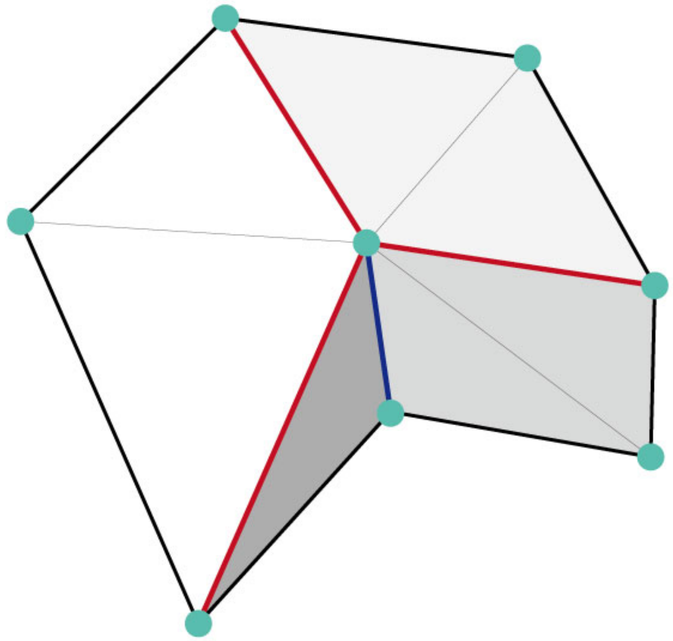
②制約と③形状探索



システムは**与えられた制約を満たすような形状を自動で見つける**

制約を満たしながらインタラクティブに形状を更新することも可能

②制約と③形状探索



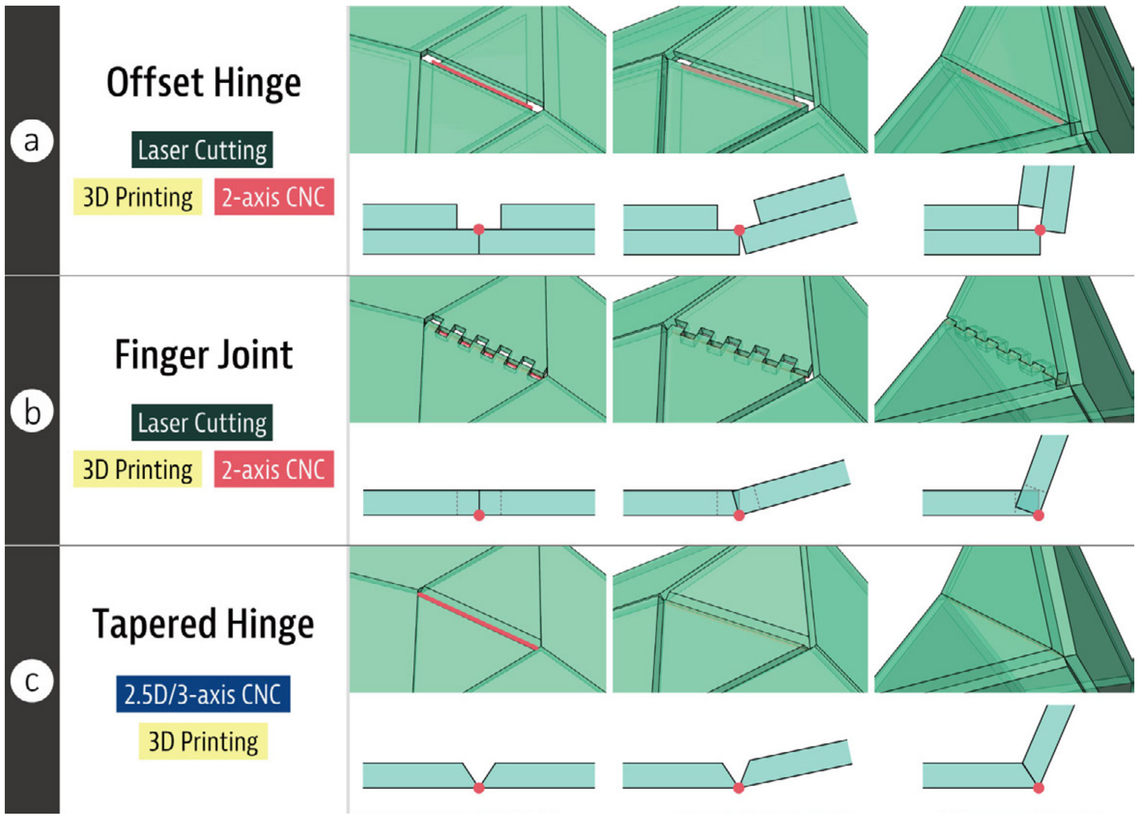
$$\arg\min \mathbf{C}(\mathbf{X}) = \begin{pmatrix} c_1(\mathbf{X}) \\ c_2(\mathbf{X}) \\ \vdots \\ c_m(\mathbf{X}) \end{pmatrix}$$

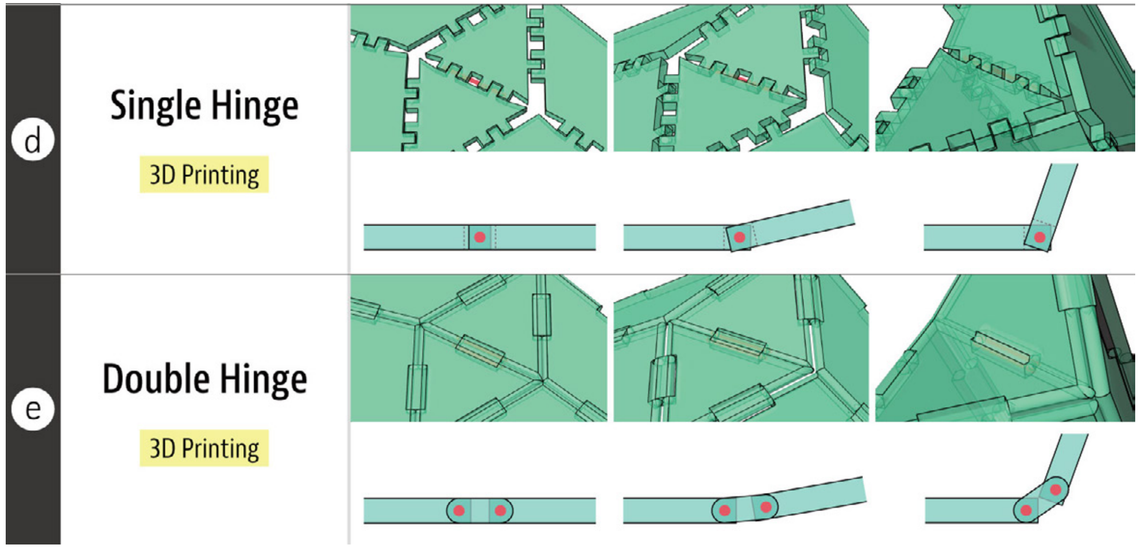
$$\Leftrightarrow \mathbf{X} \;\; s.t. \;\; \mathbf{C}(\mathbf{X}) = \mathbf{0} \in \mathbb{R}^m$$

目標は $|V|$ 個の頂点の3次元座標ベクトル $\mathbf{X} \in \mathbb{R}^{n=3|V|}$ を決定すること

このとき、各行が1つ１つの制約に対応したm行の制約関数 $\mathbf{C}(\mathbf{X}) : \mathbb{R}^n \longmapsto \mathbb{R}^m$ を一般化ニュートン法で最小化

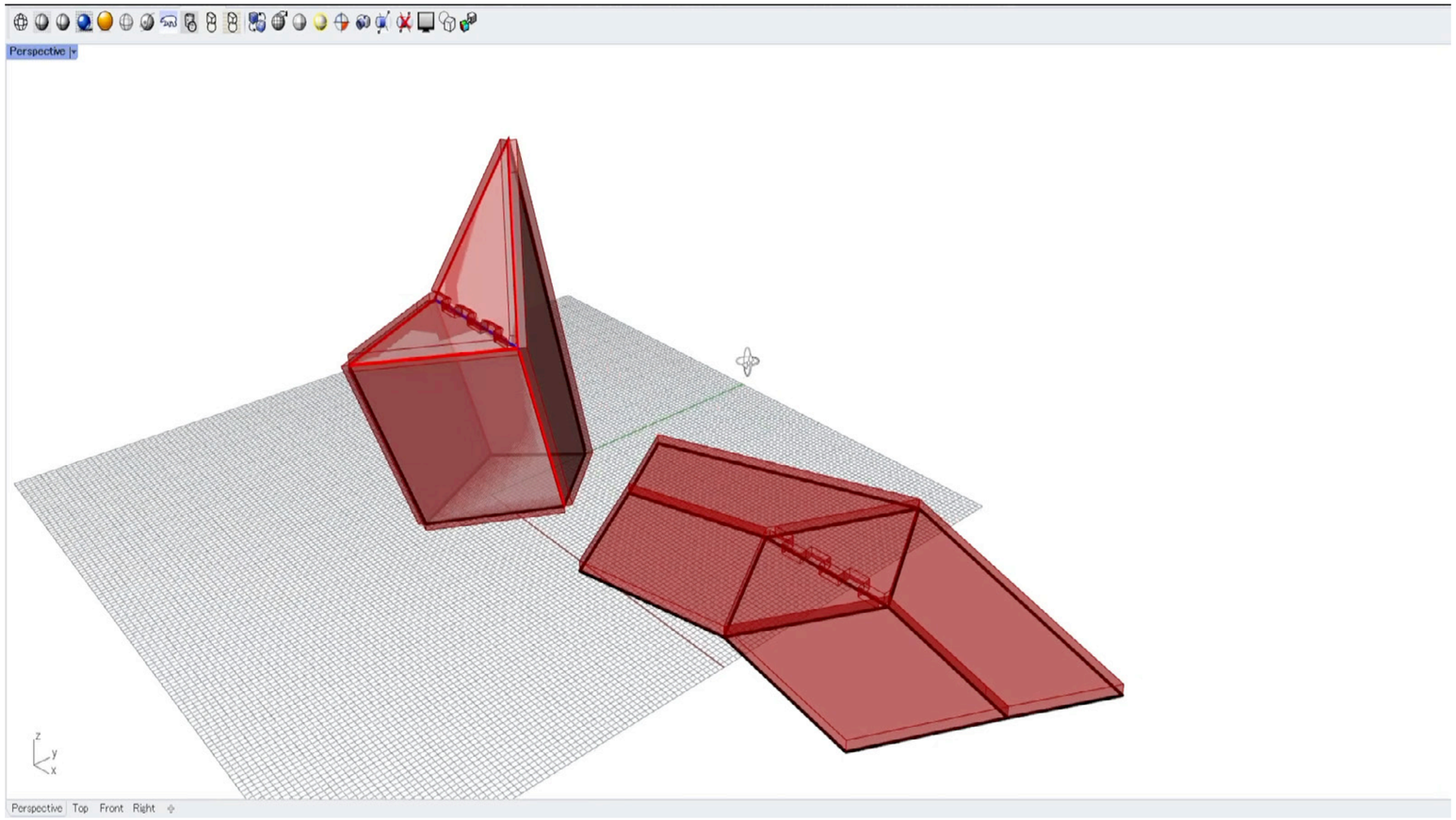
④ファブリケーション





システムは素材の厚み・折り角度・製造方法に応じて異なるヒンジ構造を割り当てる

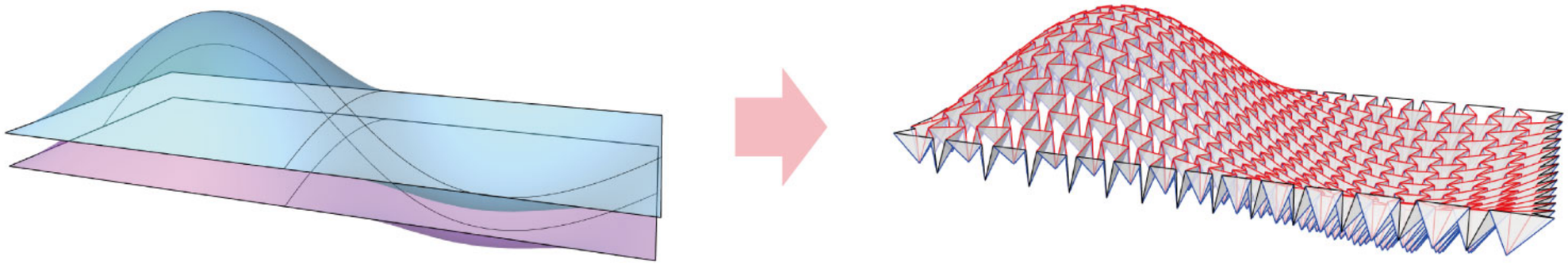
④ファブリケーション



使い方に合わせてユーザは製造方法を切り替えることができる

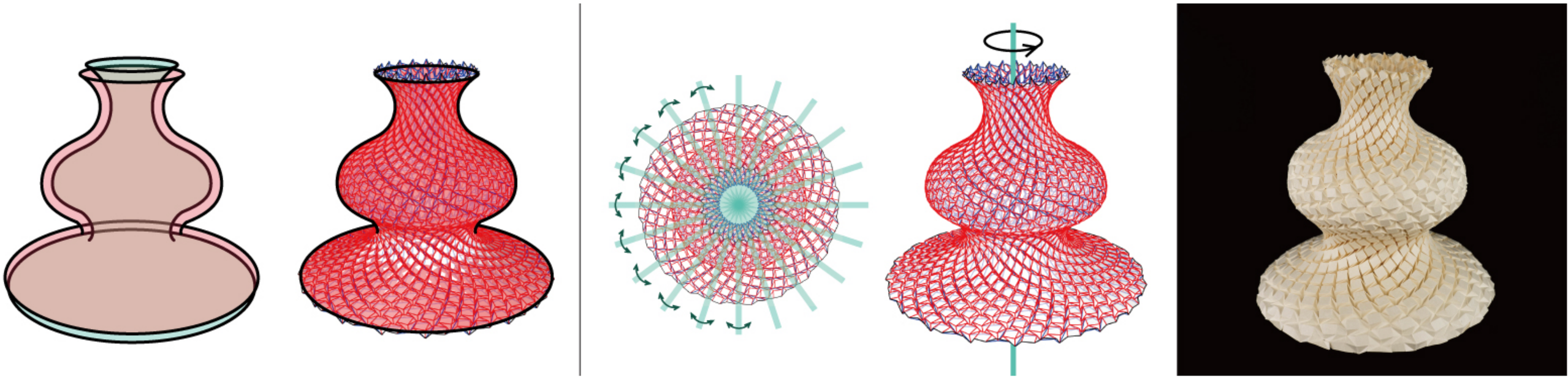
Other Functions

その他の設計手法：2つのオフセット曲面の充填



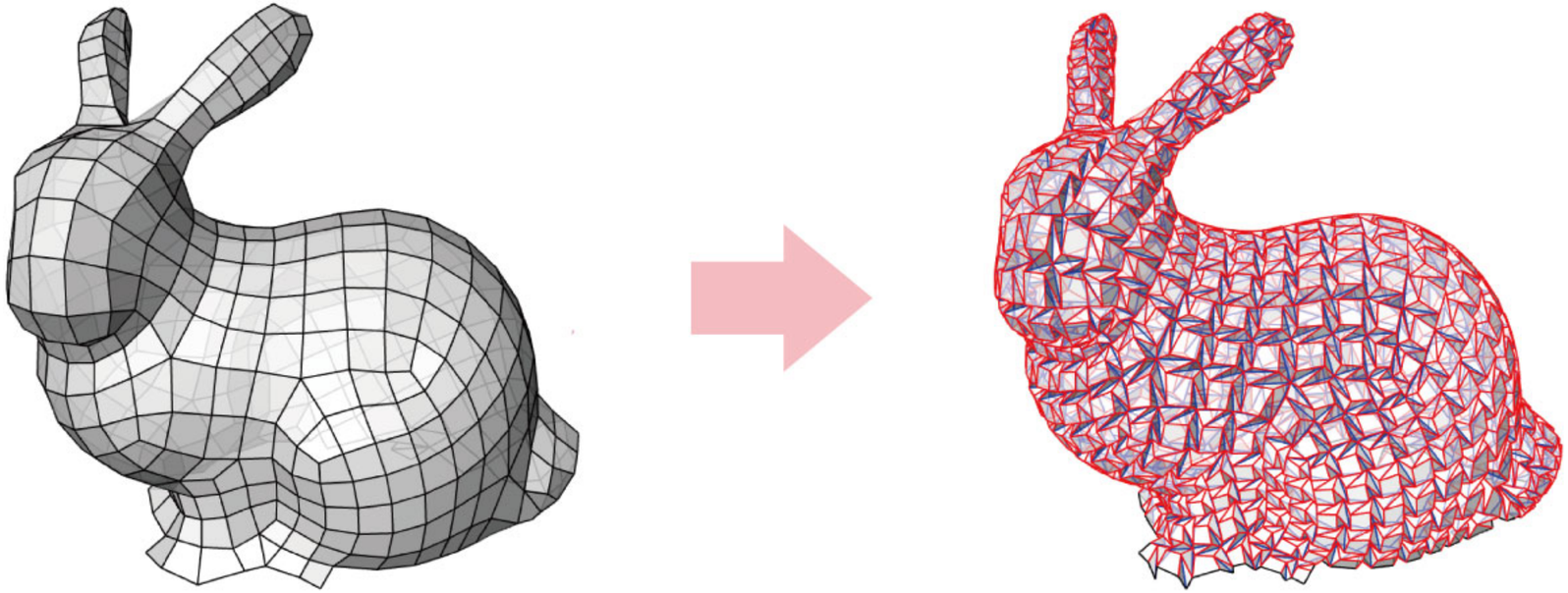
オフセットされた曲面を与えると、その間を充填するテセレーションを自動出力

ランプシェード



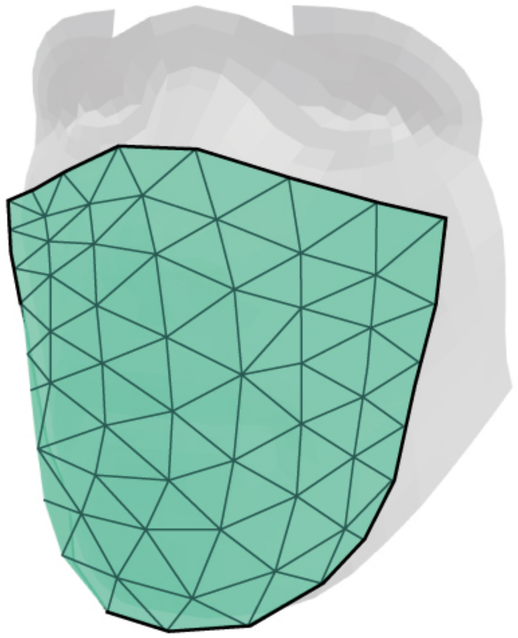
パターンはオフセットした曲面に合わせて自動的に生成されている
形状は回転対称性の制約を満たすように作られている

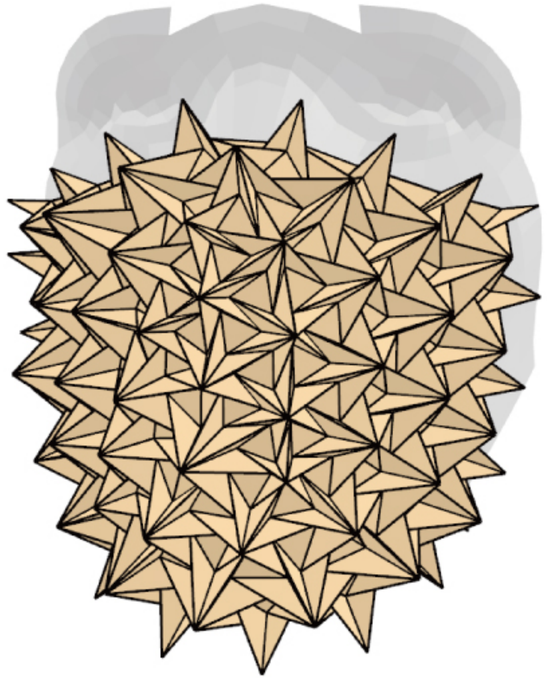
Generalized Ron Resch pattern



任意の3Dメッシュを入力として、それを折れるGeneralized Ron Reschパターンを出力

マスク





顔表面にフィットする3Dメッシュに合わせてマスクのパターンが自動生成される

CRANE

with A-POC ABLE ISSEY MIYAKE


© A-POC ABLE ISSEY MIYAKE

TYPE-V Nature Architects project

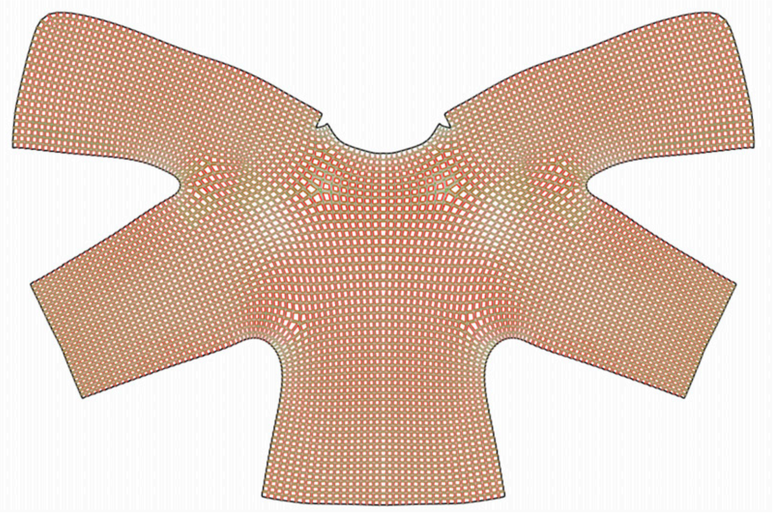
April 2023, in Milan, Italy

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)

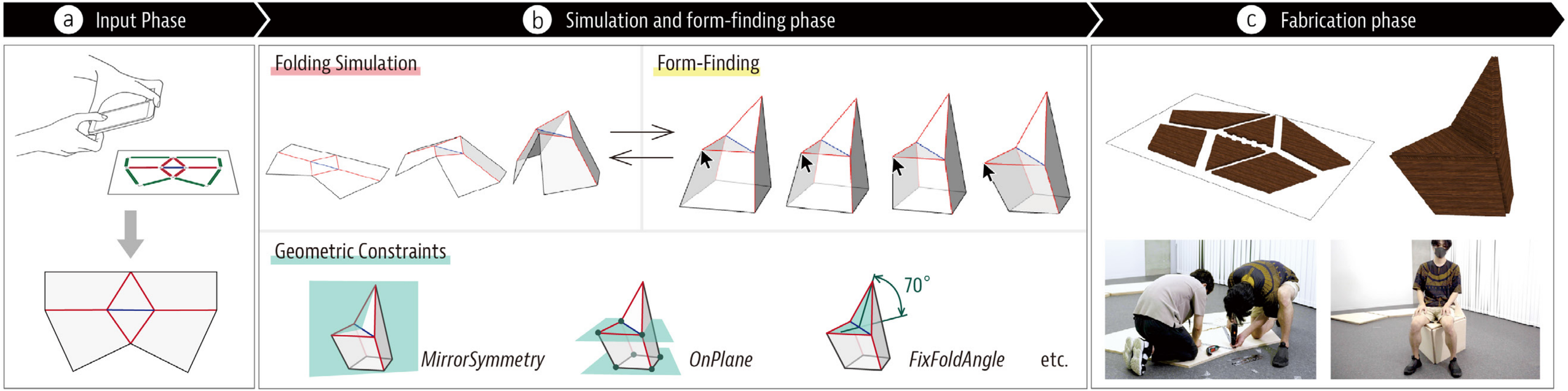
Salone del Mobile Milano 2023 at ISSEY MIYAKE / MILAN, © A-POC ABLE ISSEY MIYAKE

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

There are many fabrication papers published every year,
but we are proud of our paper **applied to the REAL design and industry.**

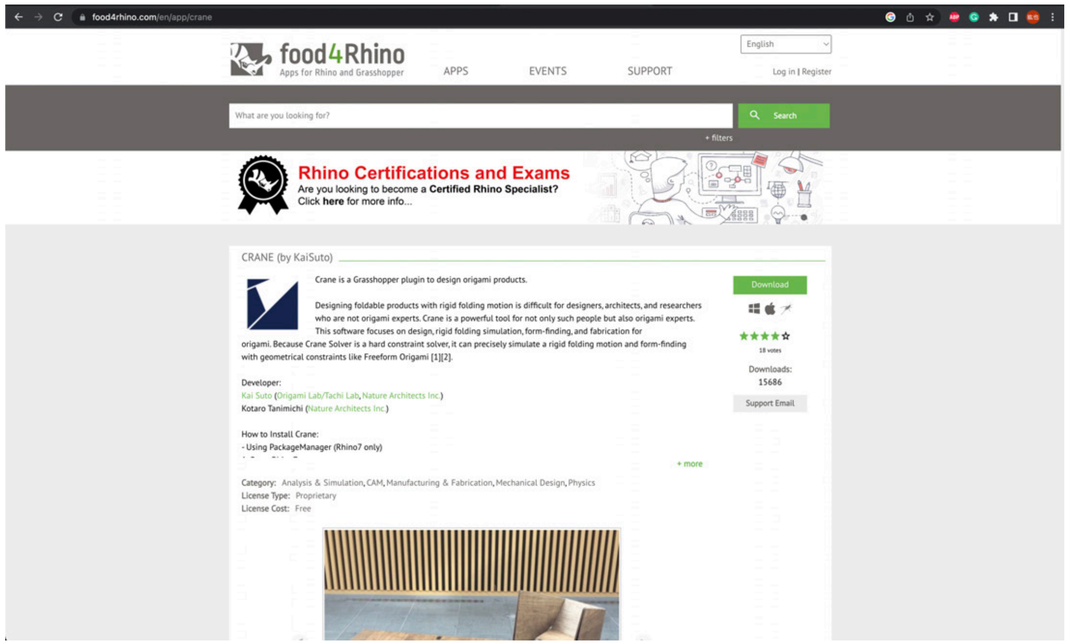
Conclusions

まとめ



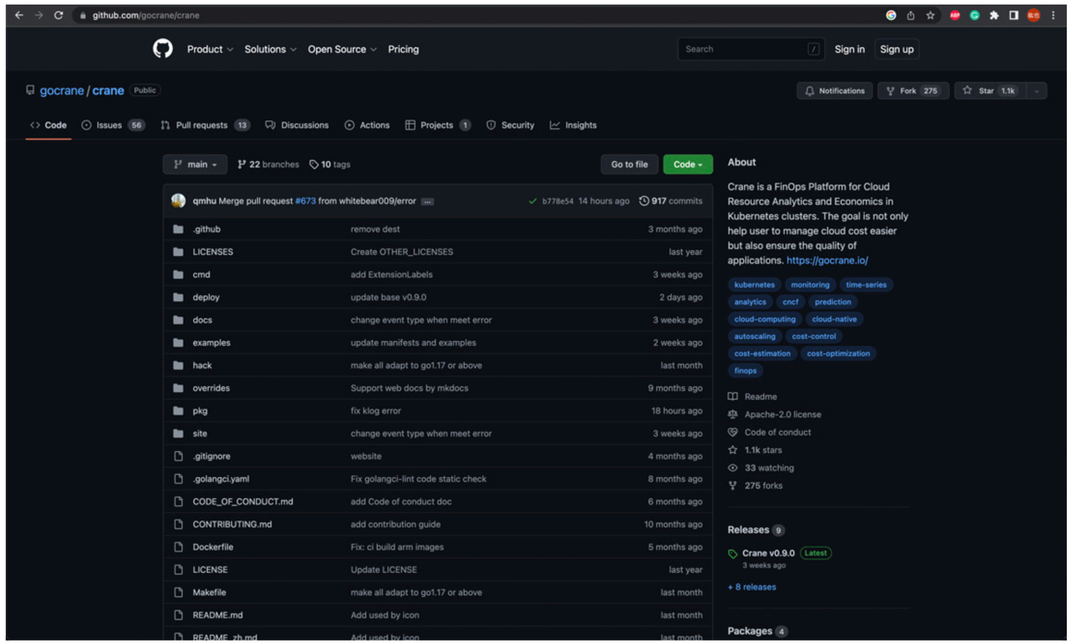
Craneは、**折紙プロダクト**の設計・製造を支援する**シームレスなデザインプラットフォーム**
ユーザによる**入力**・**シミュレーション**・**形状探索**・**製造用モデルの出力**が可能

Craneはプラグインもソースも公開済み



Food4Rhino

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

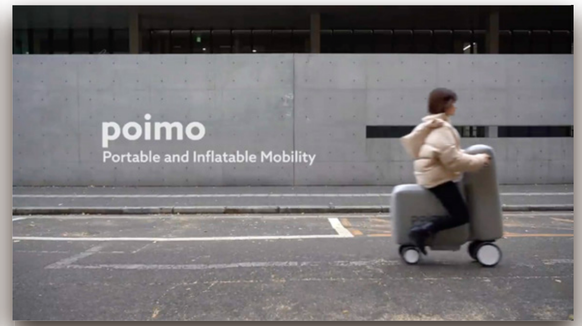


GitHub

https://github.com/gocrane/crane

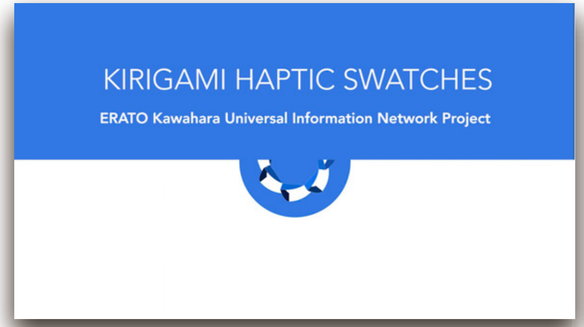
Liquid Pouch Motors
ICRA2017 + RoboSoft2020

Self-healing UI
UIST2019



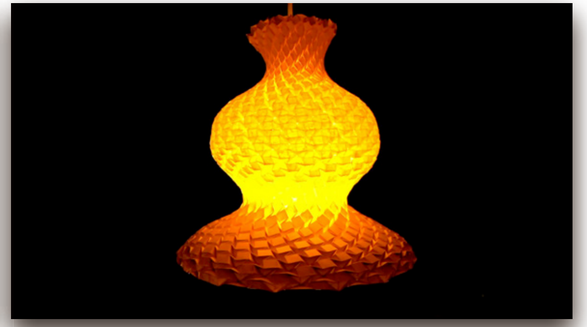
poimo
CHI EA 2020 & UIST2020

Pop-up Print
UIST2020



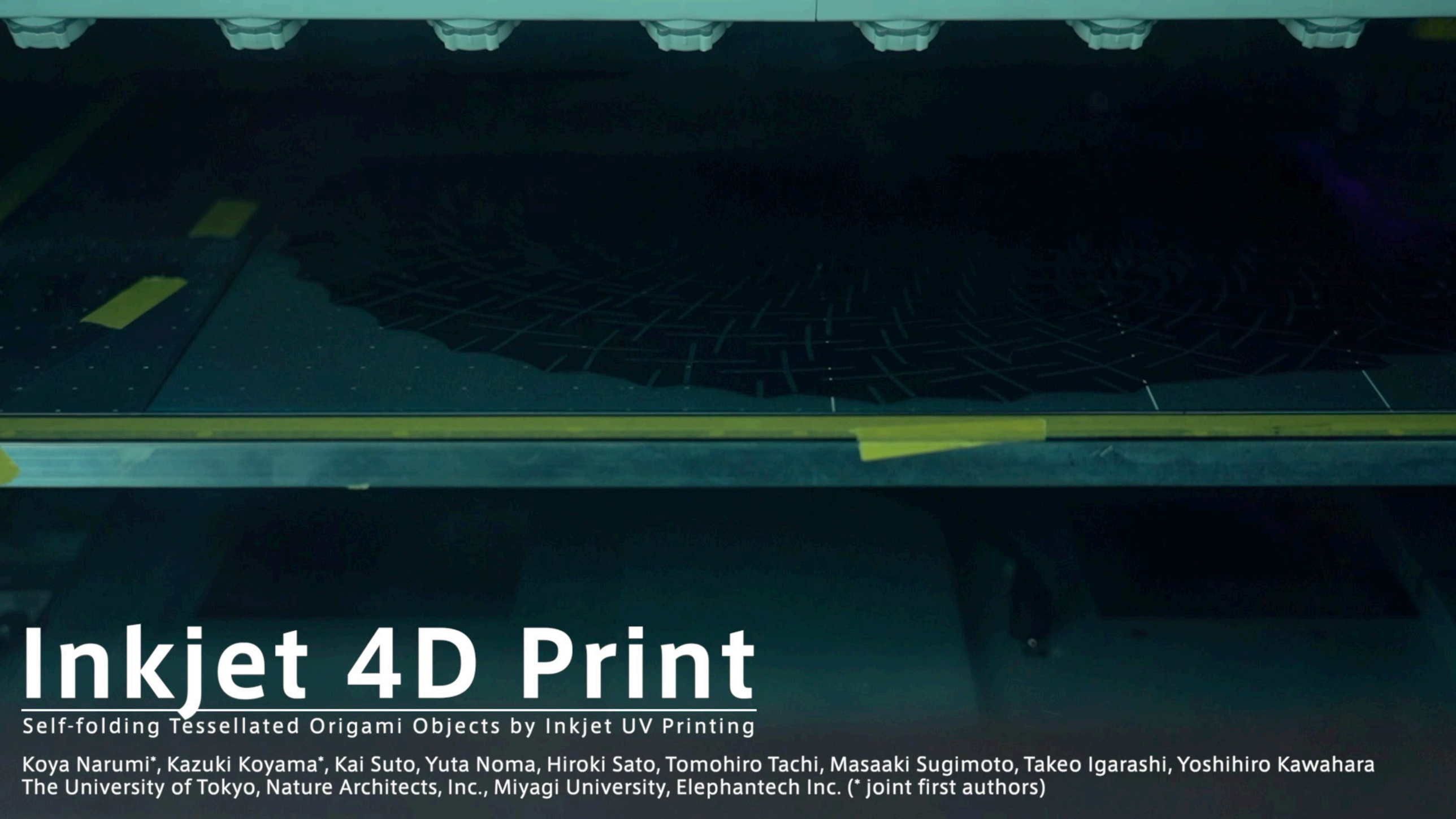
Kirigami Haptic Swatches
CHI2020

Flower Jelly Printer
CHI2021



Crane
TOCHI (CHI2023)

Inkjet 4D Print
TOG (SIGGRAPH2023)

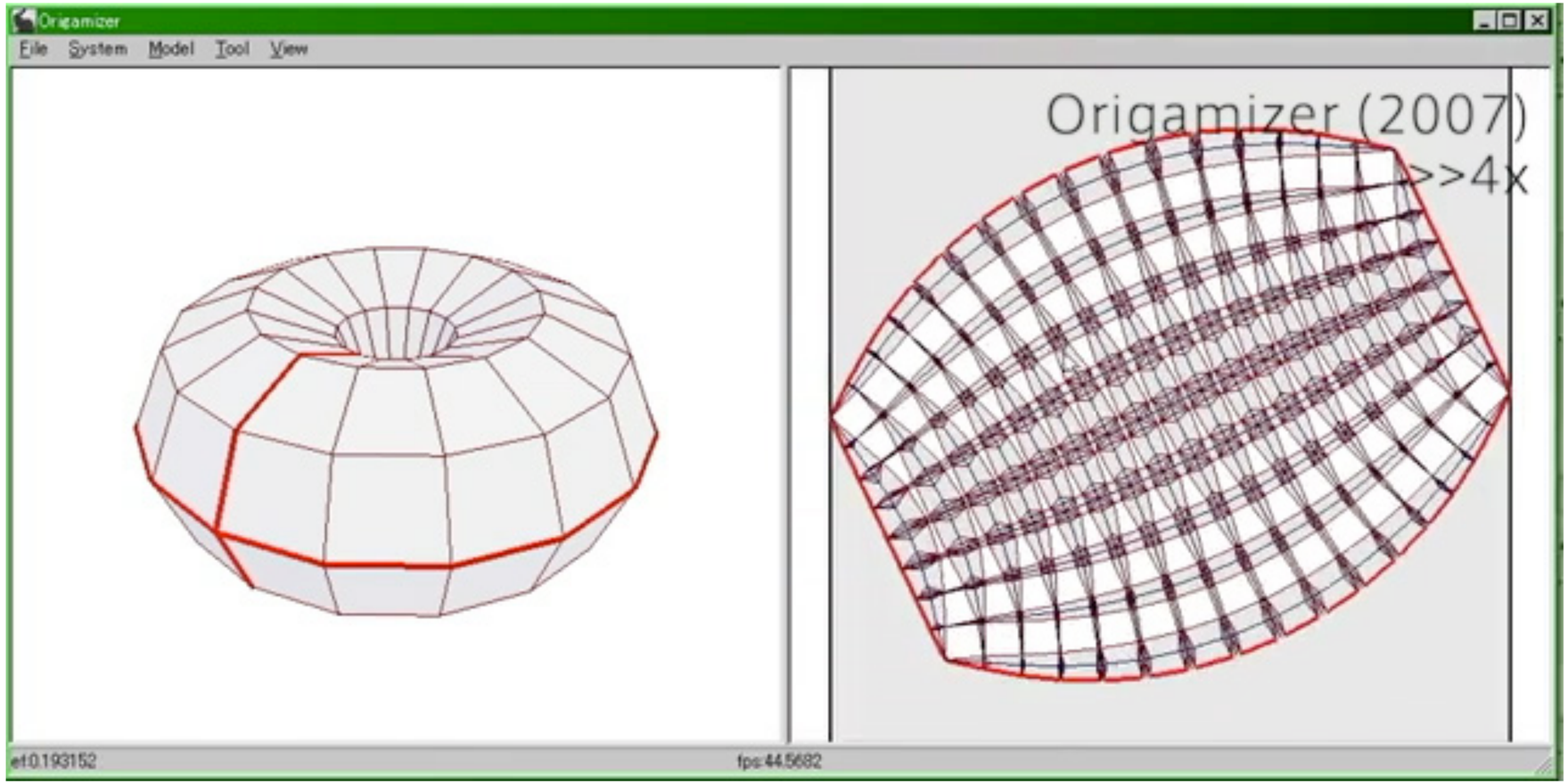


Inkjet 4D Print

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)

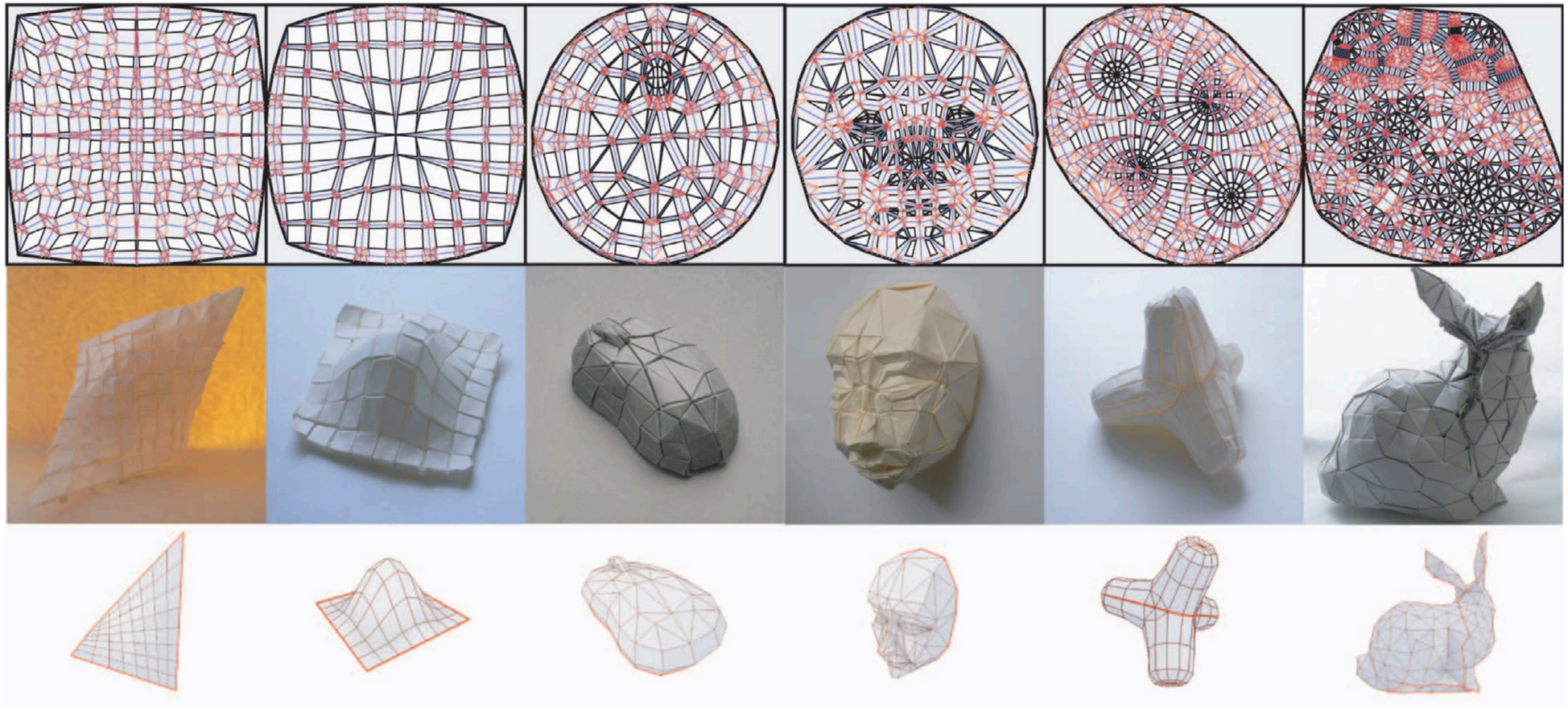
あらゆる多面体は一枚の紙から折れる



[1]

2017年、DemaineとTachiによりあらゆる多面体が一枚の紙から折れることが証明された [2]

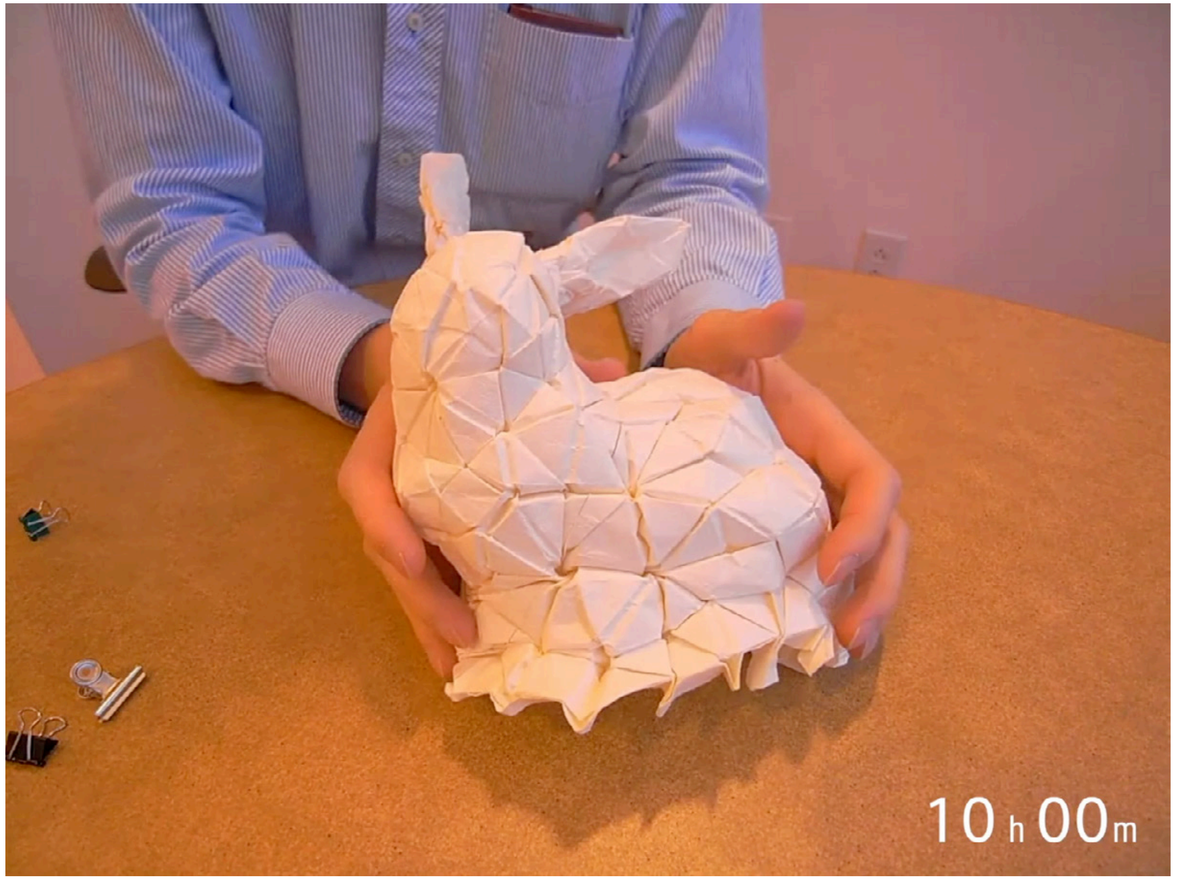
あらゆる多面体は一枚の紙から折れる



[1]

2017年、DemaineとTachiによりあらゆる多面体が一枚の紙から折れることが証明された [2]

折紙を折るのにはとても長い時間が必要

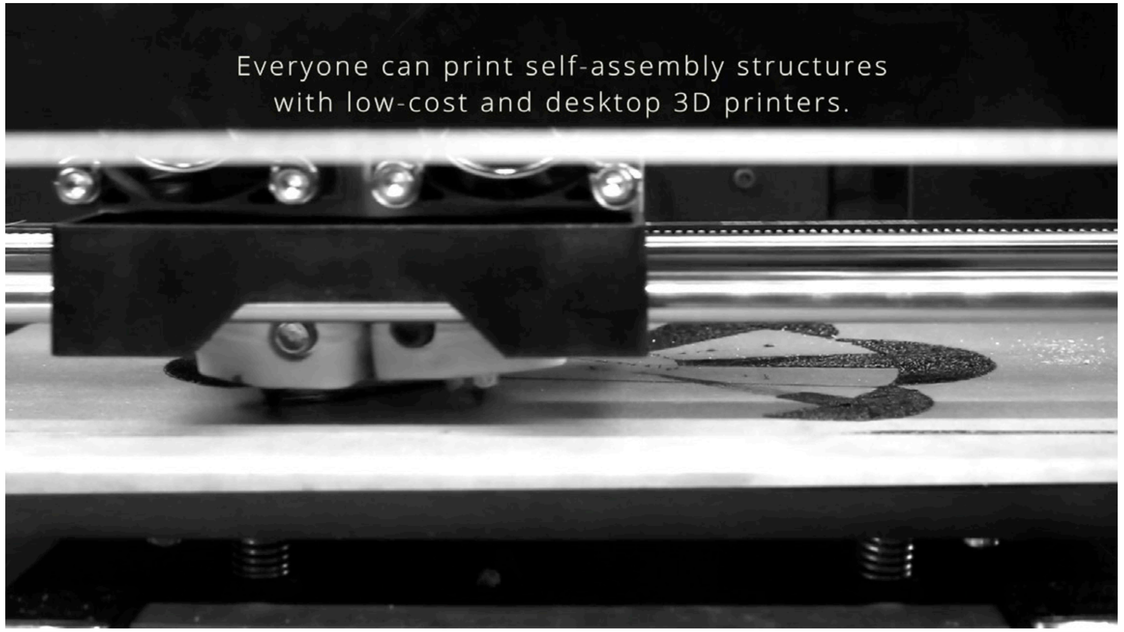


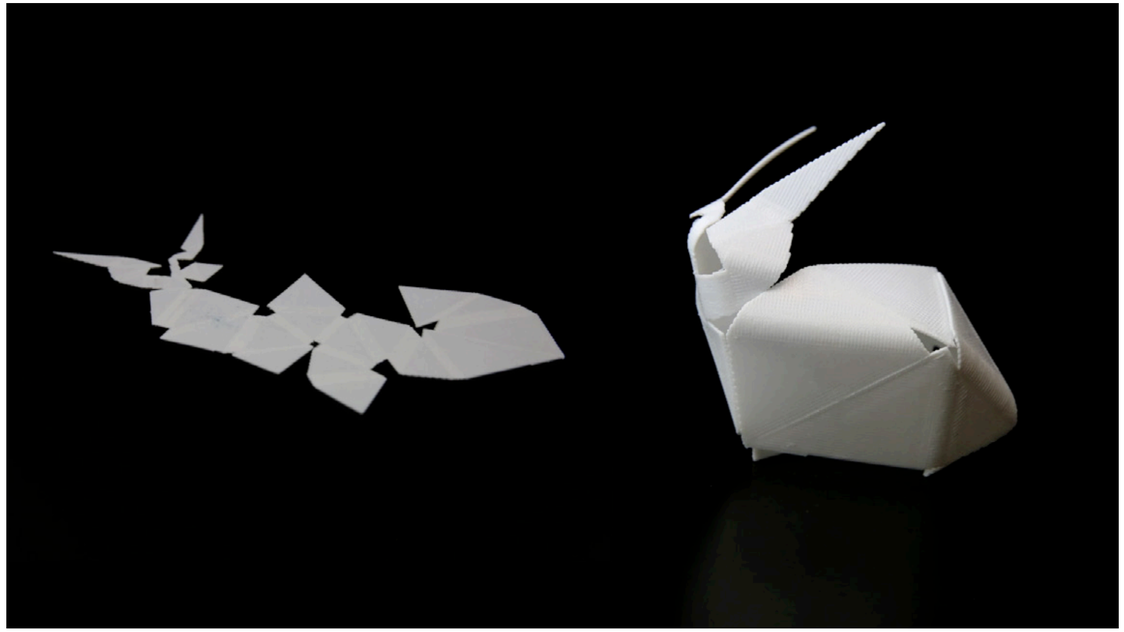
[1]

パターンの設計は数秒から数分で済むが、実際に折るのには**数時間から数十時間**が必要

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

関連研究：自己折りのための4Dプリント



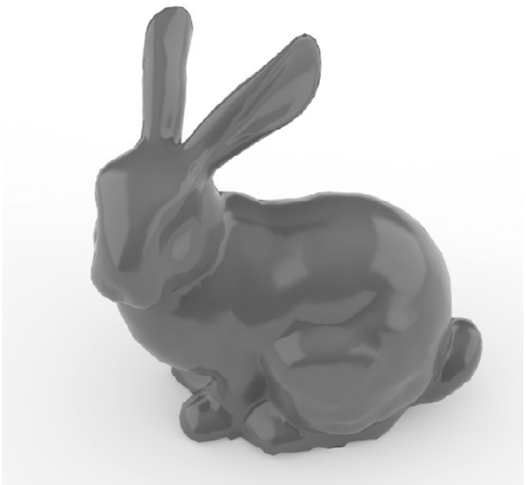


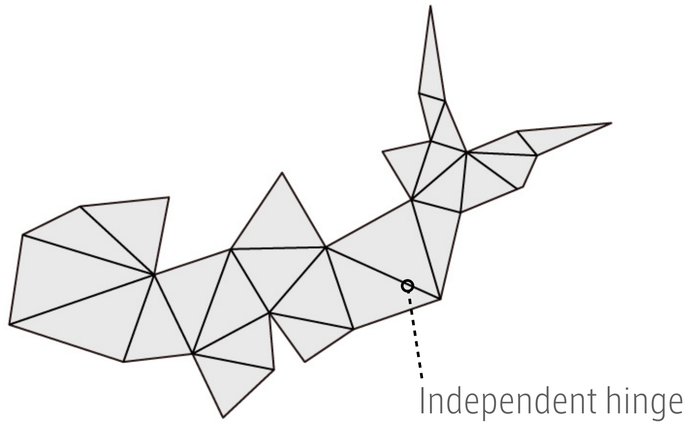
[1]

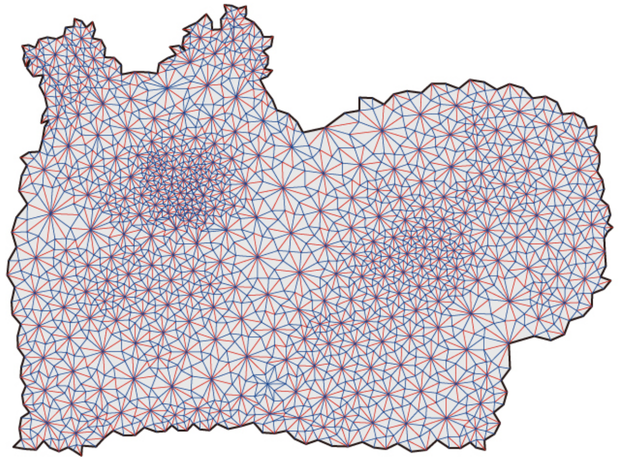
4Dプリントは、縦横高さの3次元の印刷に加えて**時間的な形状変化**を引き起こす

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

既存の4Dプリントではまったく足りない

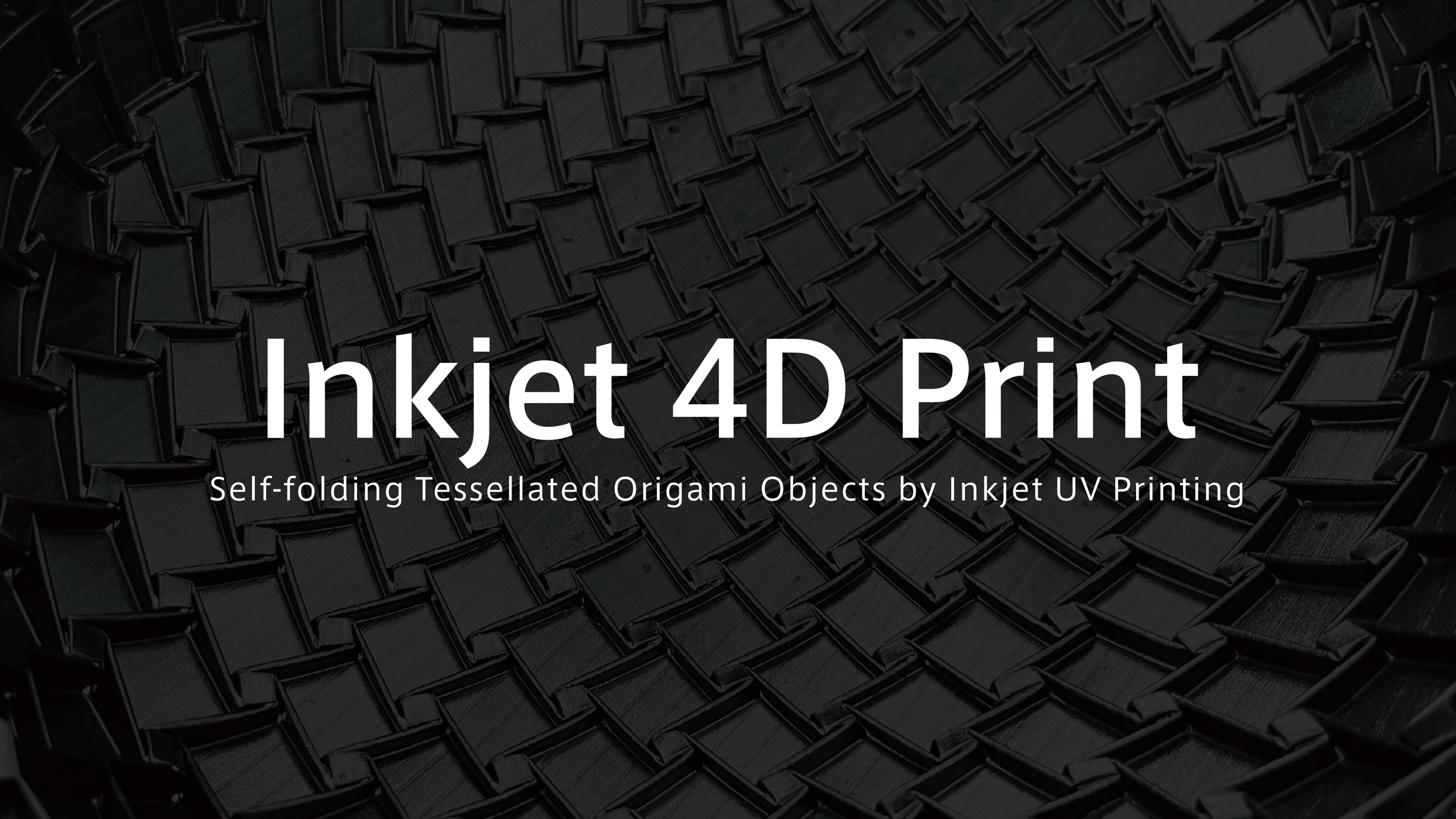






	既存の4D Printing [1]	折紙研究者が望むパターン
面の数	26	4299
ヒンジの特性	Independent	Dependent
ハードウェア	FDM 3D printer	???

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

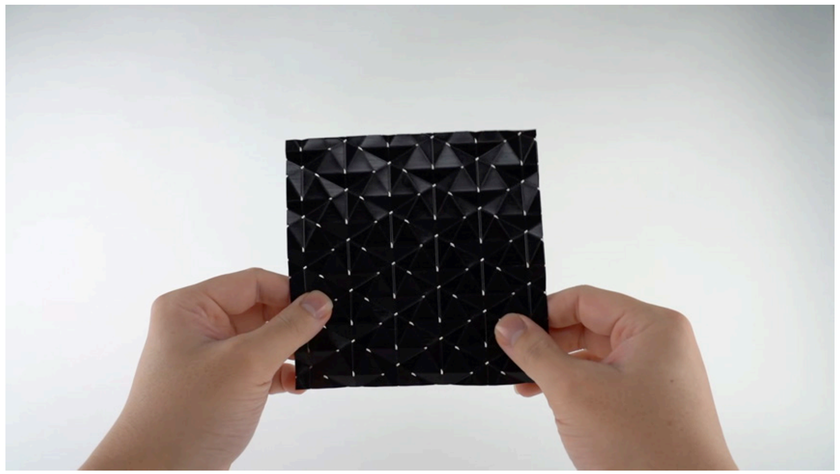


Inkjet 4D Print

Self-folding Tessellated Origami Objects by Inkjet UV Printing

Inkjet 4D Print: 概要

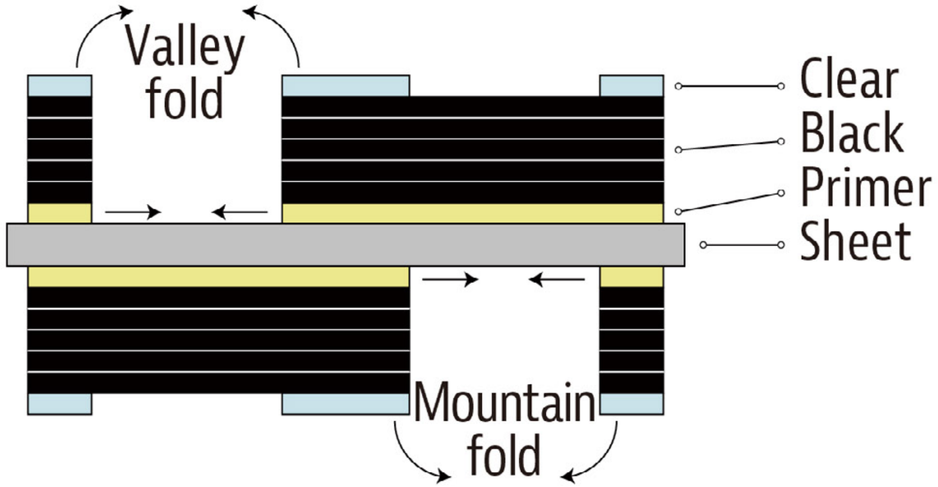
商用のUVプリンタによる
インクジェットプリント

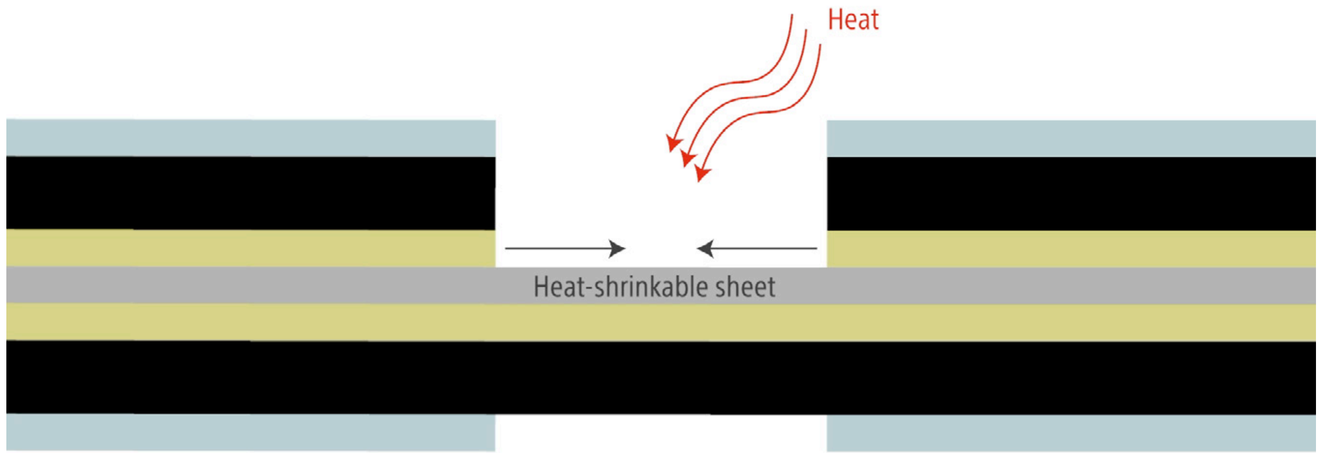


折紙のパターン
熱収縮シート + UVインク

70度のお湯による
自己折り

原理

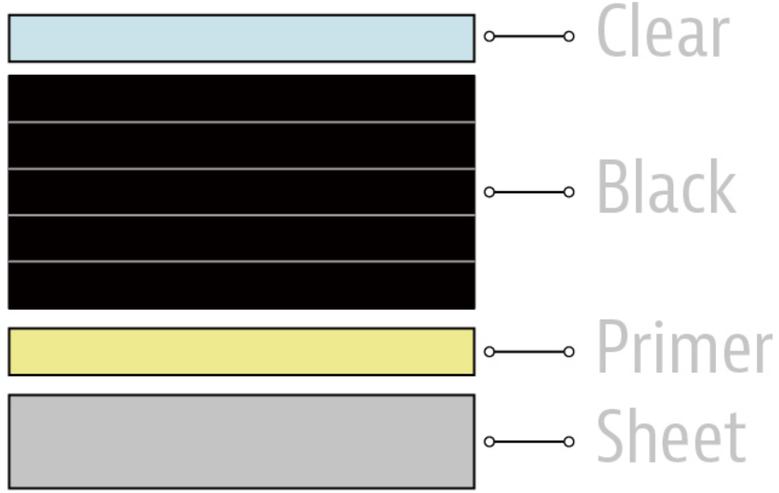


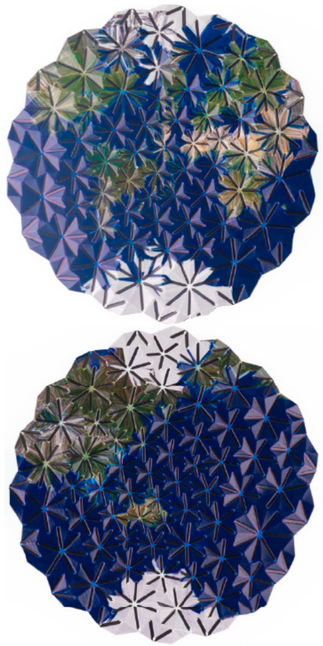


熱収縮シートの収縮が黒インクにより部分的に阻害される

ギャップ幅により**折り角度を線形に制御可能**

色の付与

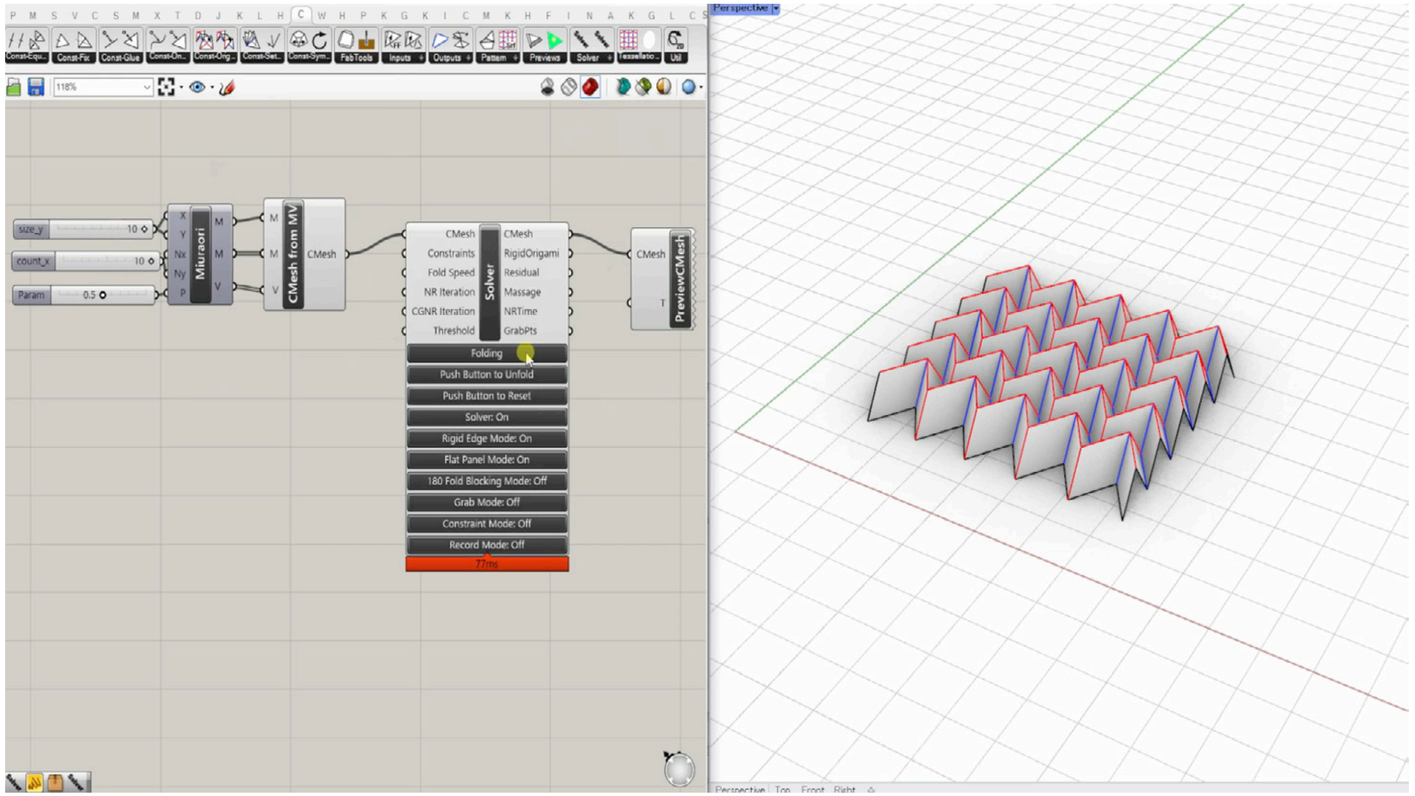




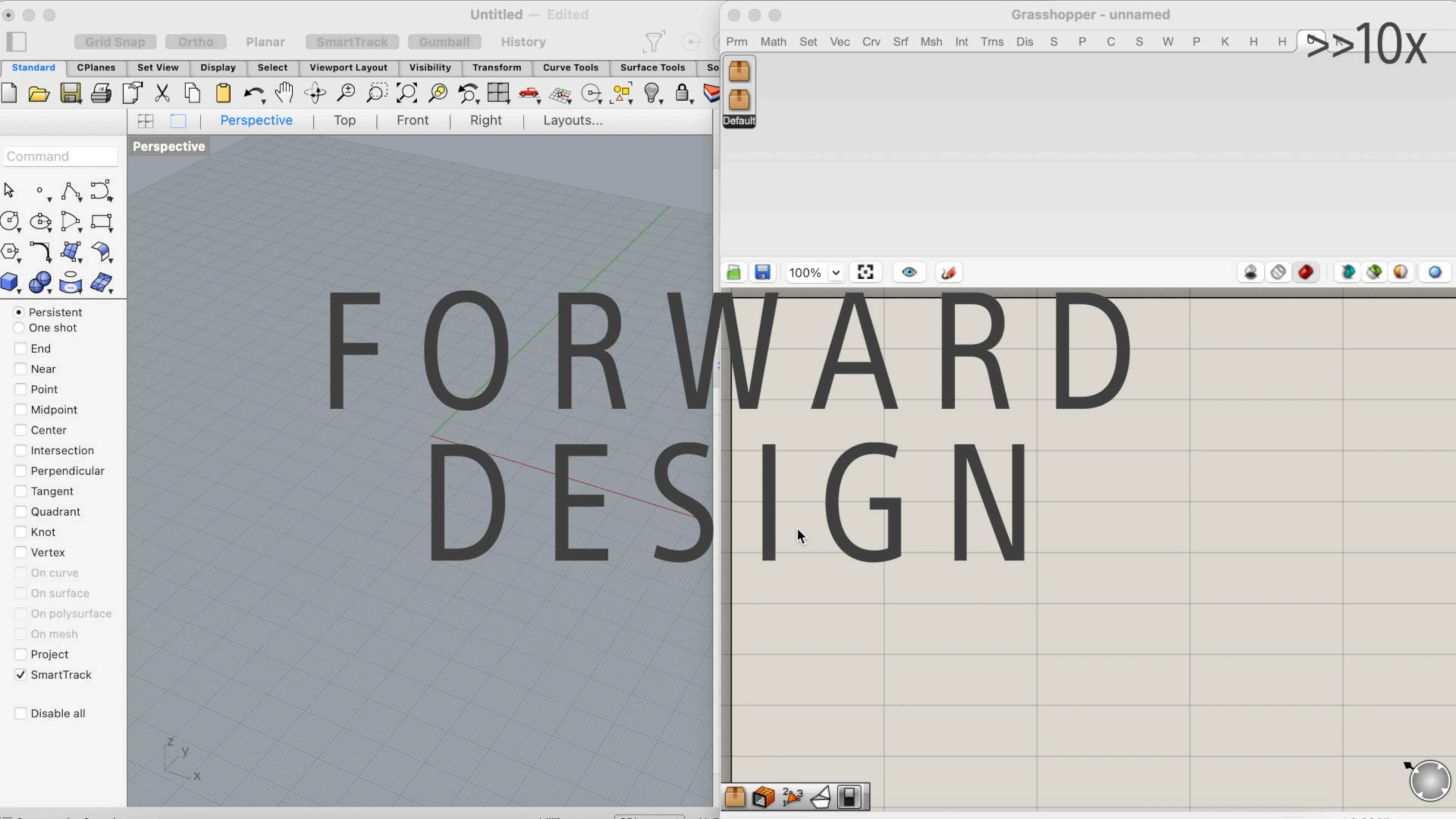
形状の変化と**色の装飾**を1回の印刷プロセスで実現可能

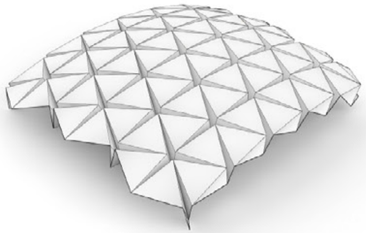
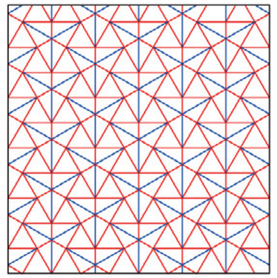
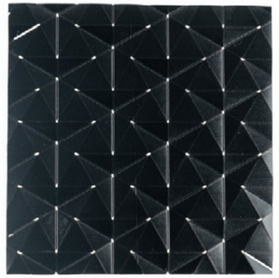
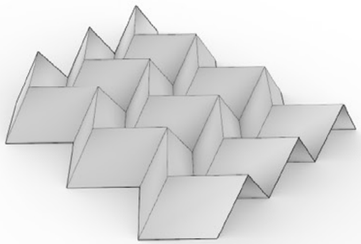
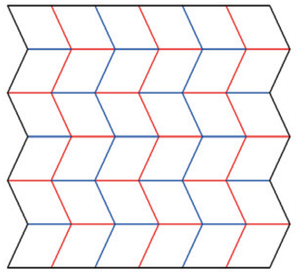
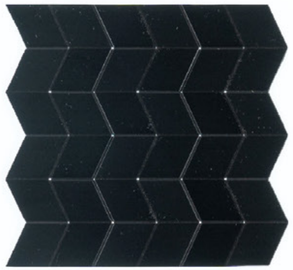
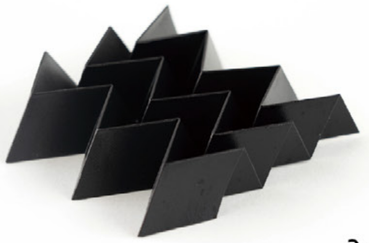
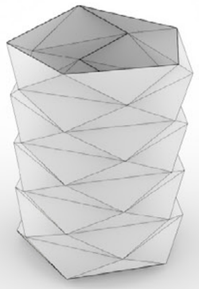
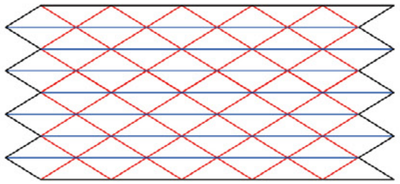
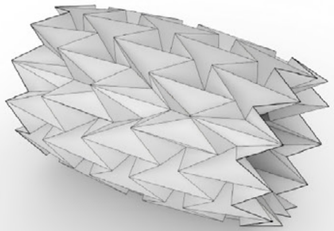
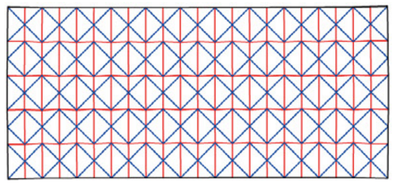
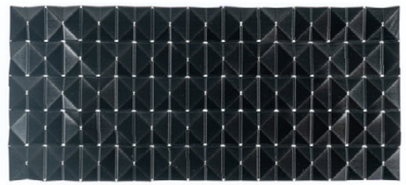

Software &
Design Examples

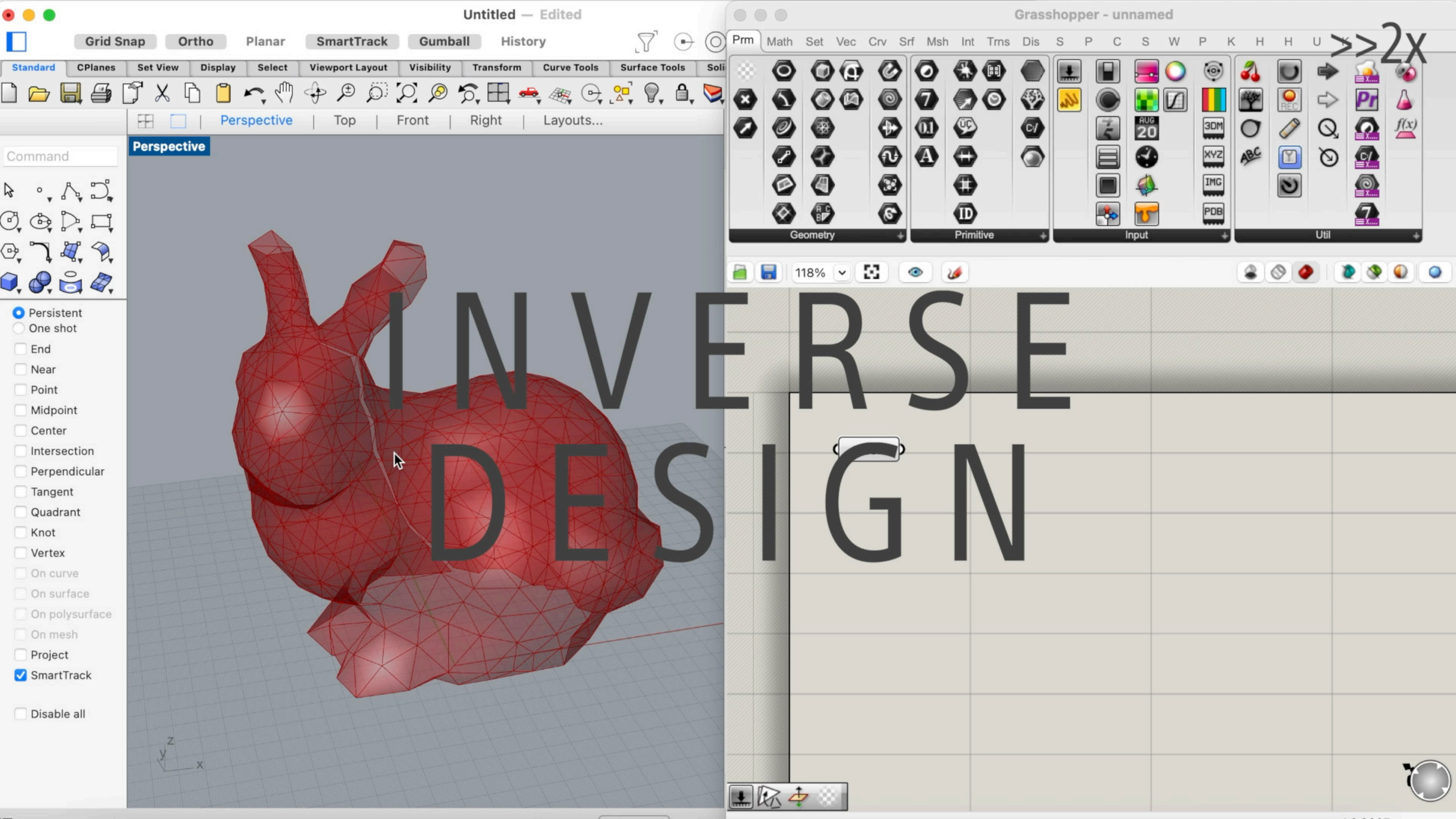
ソフトウェアの概要

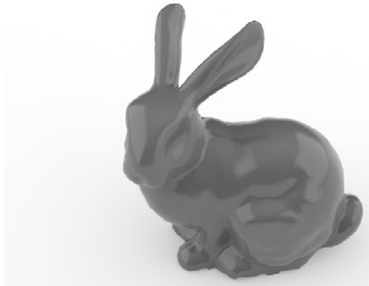
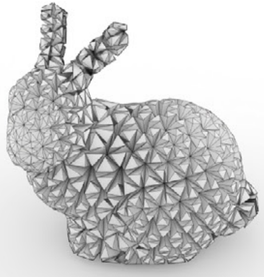
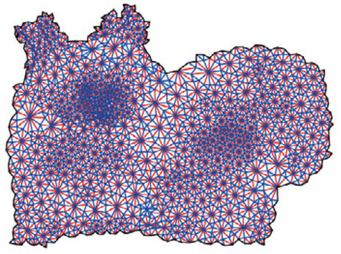
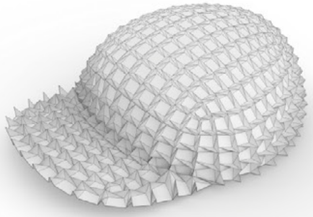
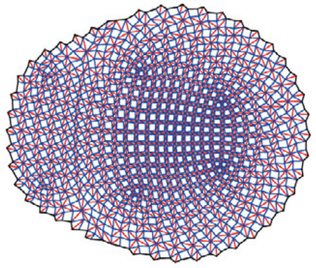
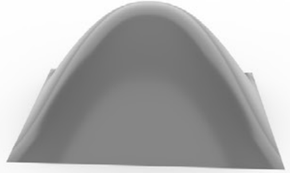
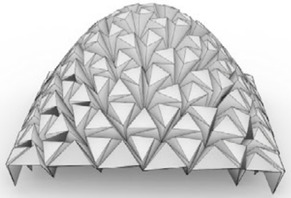
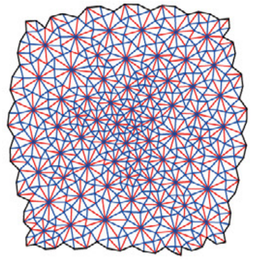
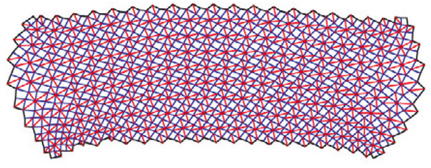
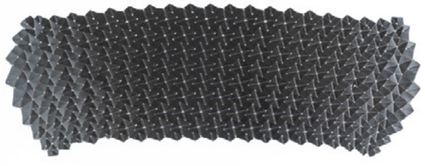


GUIはRhino/Grasshopper上に実装されている
画面の左側にビジュアル言語、右側に折紙のシミュレーション結果が表示される


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

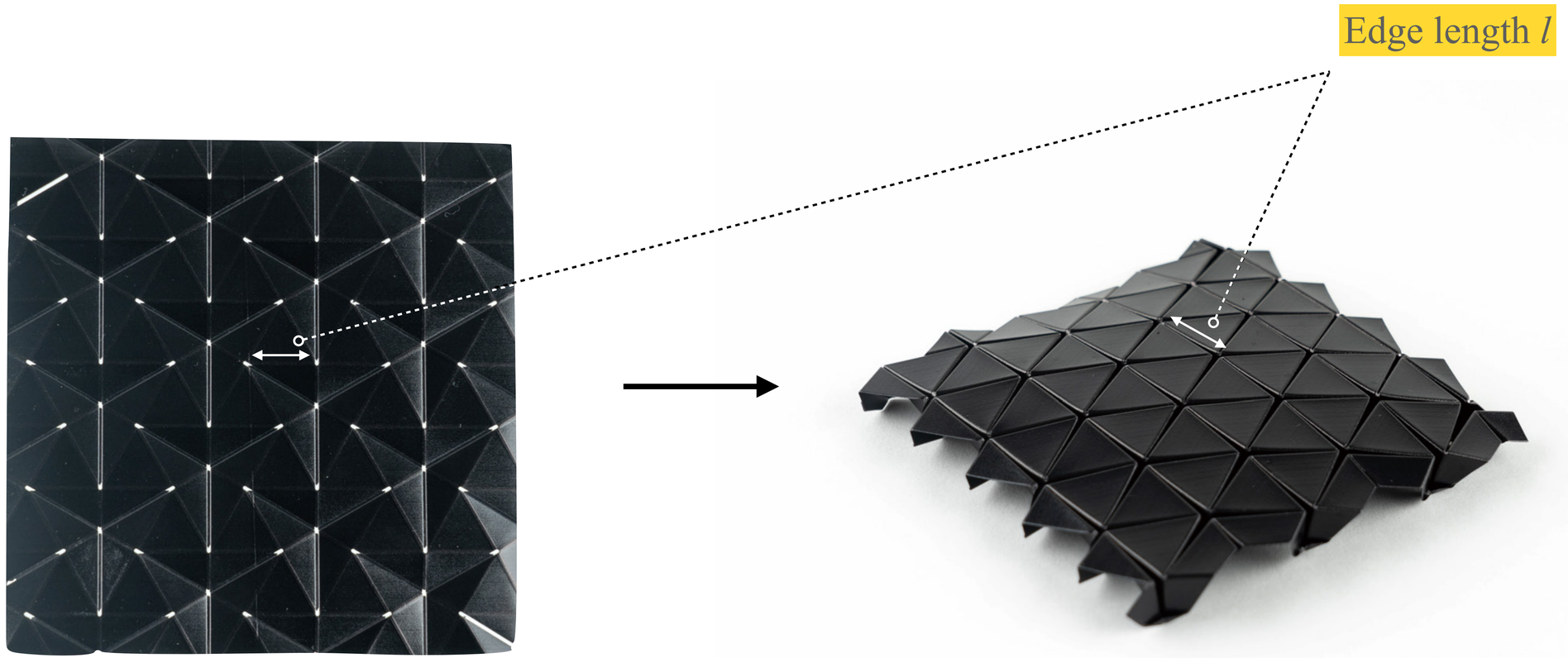
Name 2D origami size	3D model	2D model	2D photo	3D photo
Ron Resch pattern 267 facets 130 mm x 130mm				 3 cm
Miura folding 36 facets 140 mm x 130mm				 2 cm
Yoshimura pattern 80 facets 108 mm x 64mm				 2 cm
Waterbomb pattern 330 facets 280 mm x 130 mm				 2 cm


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
>>2x
118%
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					 5 cm
Cap 3426 facets 474 mm x 402 mm					 5 cm
Mountain 1045 facets 271 x 286 mm					 3 cm
Torus 1770 facets 212 mm x 491 mm					 3 cm

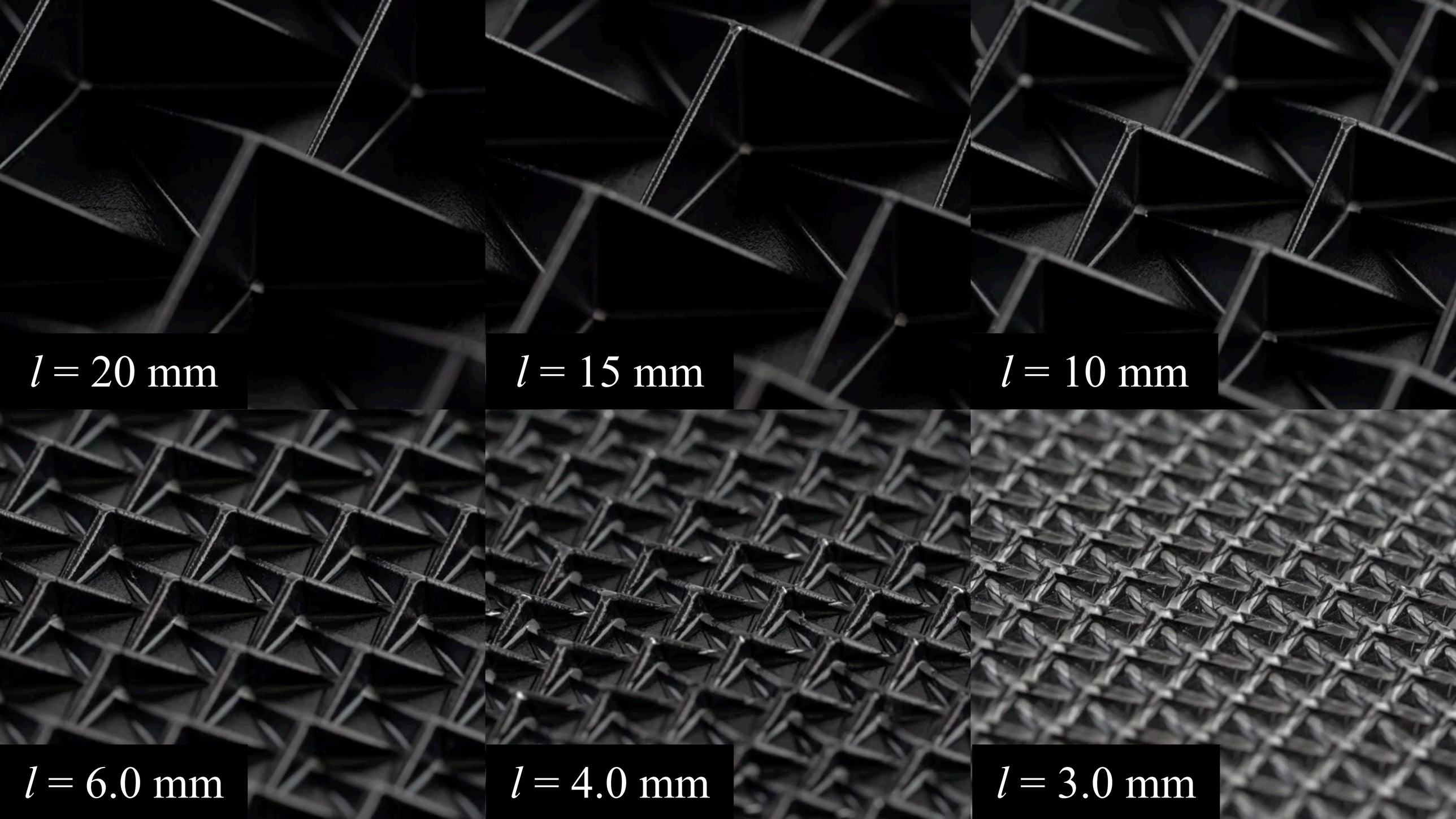

Evaluation

解像度

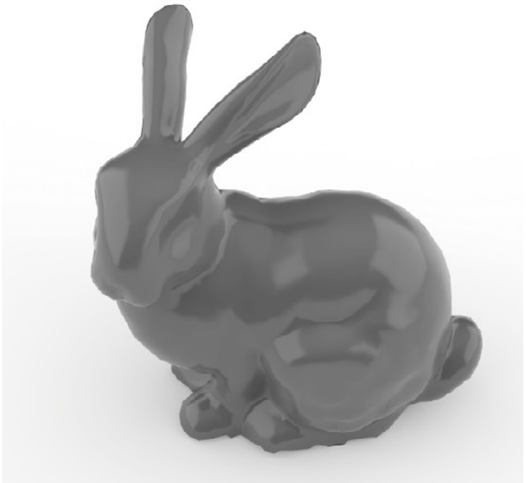


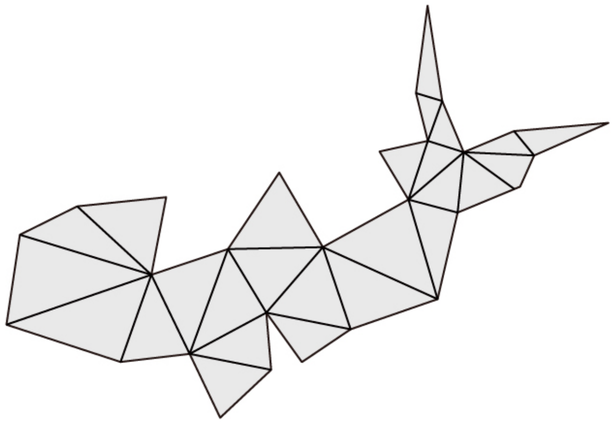
Ron Reschパターンの辺長 l により解像度を定義

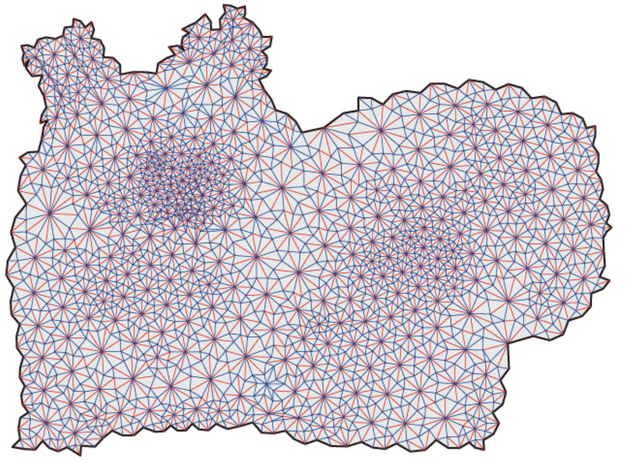
実質的な解像度は l = 3.0 mm


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

性能比較：造形の複雑さ



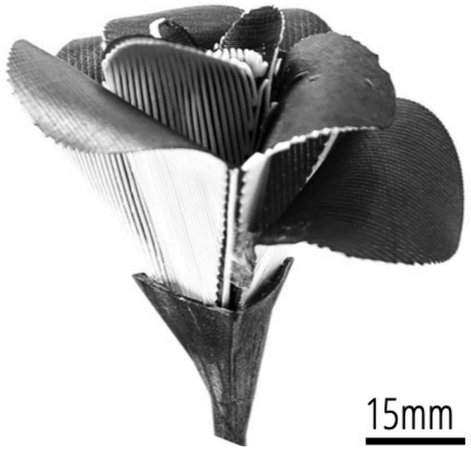


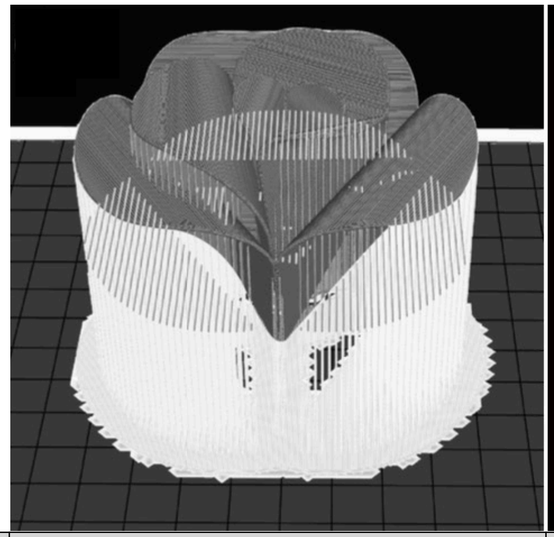


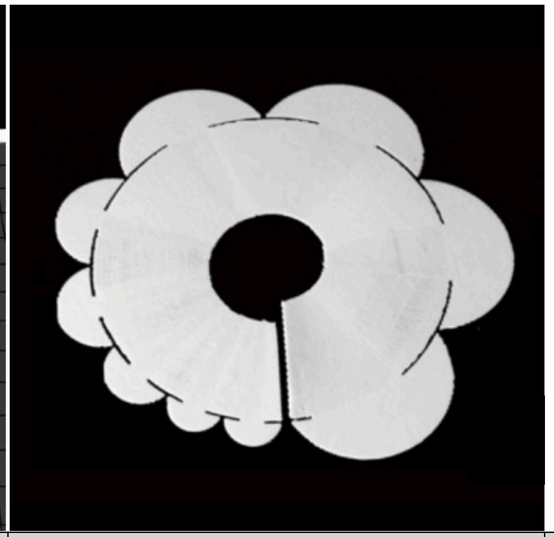
	従来の4Dプリント [1]	**Inkjet 4D Print**
ハードウェア	FDM 3D printer	Inkjet UV Printer
バニーの面の数	26	4,299 (**従来の150倍以上**)
変形できる面の最大数	69	80,008 (**従来の1200倍以上**)

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

折紙ファブは環境にやさしい



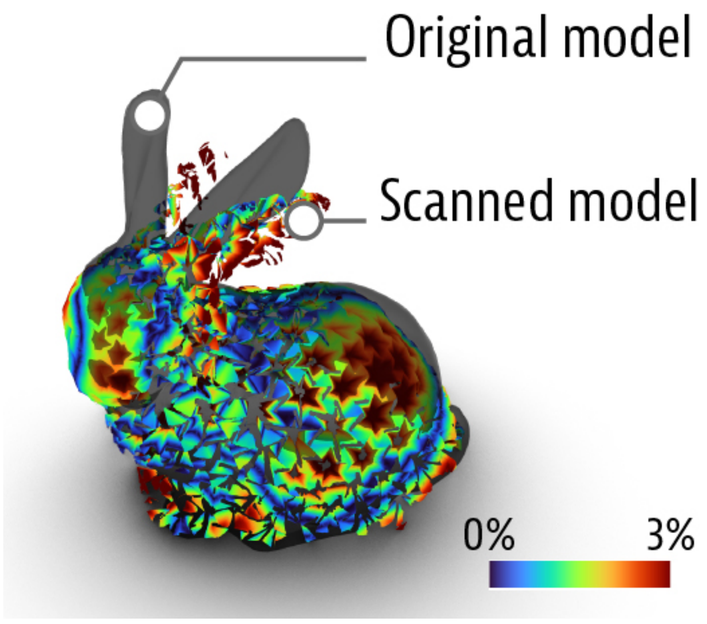




	FDM 3Dプリント [1]	従来の4Dプリント [1]	Inkjet 4D Print
サポート材消費	65 g	0 g	**0 g**
印刷時間	8 h 47 m	1 h 12 m	0 h 26 m (**1/20 of 3D printing**)
運搬・輸送	×	○	◎

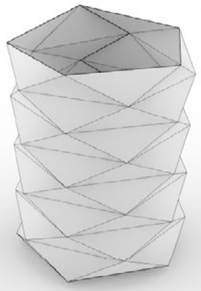
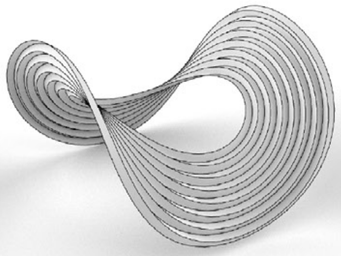
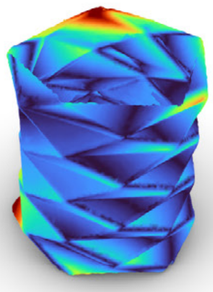
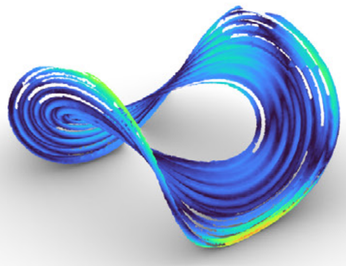
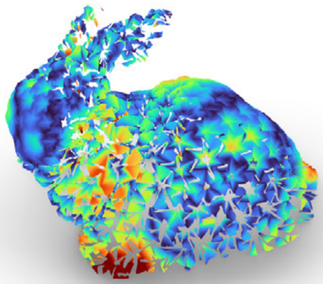
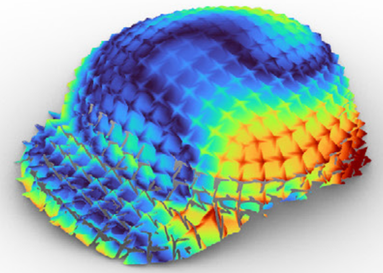
[1] An et al., Thermorph, CHI2018.

形状の精度



自己折りされた形状の精度を**3Dスキャン**により検証

元々のモデルと自己折りされた形状の距離を算出し、元のモデルの大きさで正規化

Name	Yoshimura pattern	Disk	Bunny	Cap
3D model				
Photo	 2 cm	 2 cm	 5 cm	 5 cm
Scanned data highlighting error				
Max error	4.2%	2.7%	4.7%	4.9%
Mean error	0.82%	0.68%	1.4%	1.4%


Applications

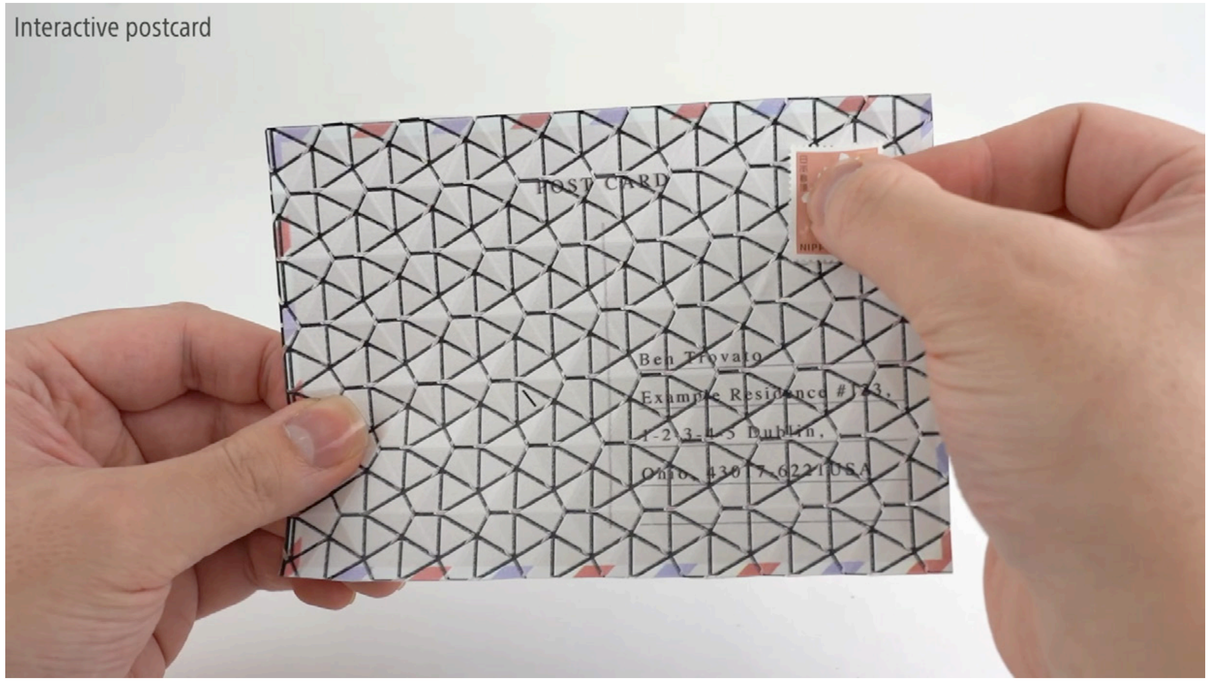
ファッションへの応用

複雑な形状と**複雑な色**を同時に実現可能。**1点もの**も可能

ボトルシップ

人間がアクセスできない場所での**自己組み立て**に応用可能

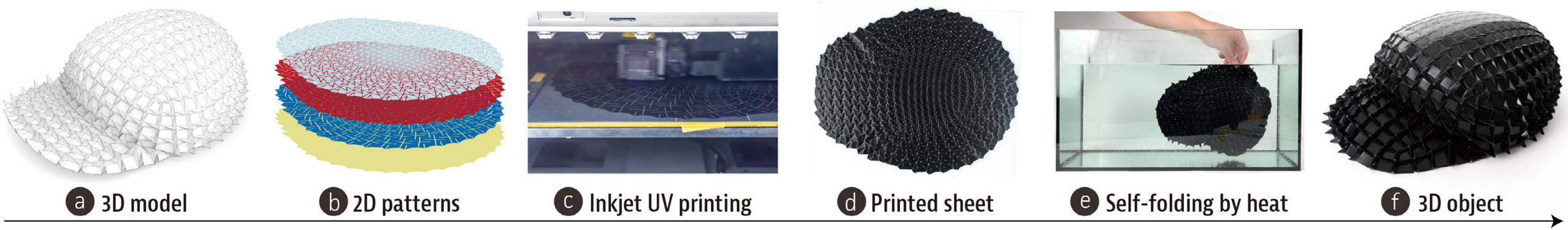
インタラクティブなポストカード



薄い形状を活かすことで、インタラクティブなポストカードによる**装飾演出**などに応用可能


Conclusions

まとめ



Inkjet 4D Print

1. **最大で数千から数万個の面**（**既存研究の1200倍以上**）を持つ複雑な折紙を自動で折ることが可能
2. 単純に3Dプリントするよりも**20倍早く**印刷可能
3. **工学的に有用なパターン**と**自由形状**の両方を折ることが可能
4. 1回の印刷で**形状変化**と**色の装飾**を同時に付与可能

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**

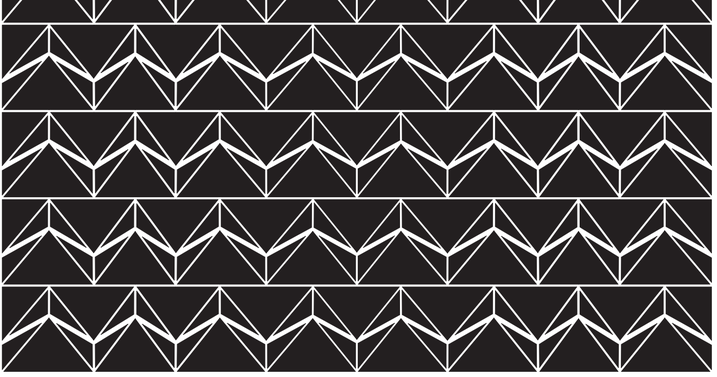
ホイポイカプセルって実現できるの？「持ち運べる乗り物」を開発する工学の専門家に聞いてみた

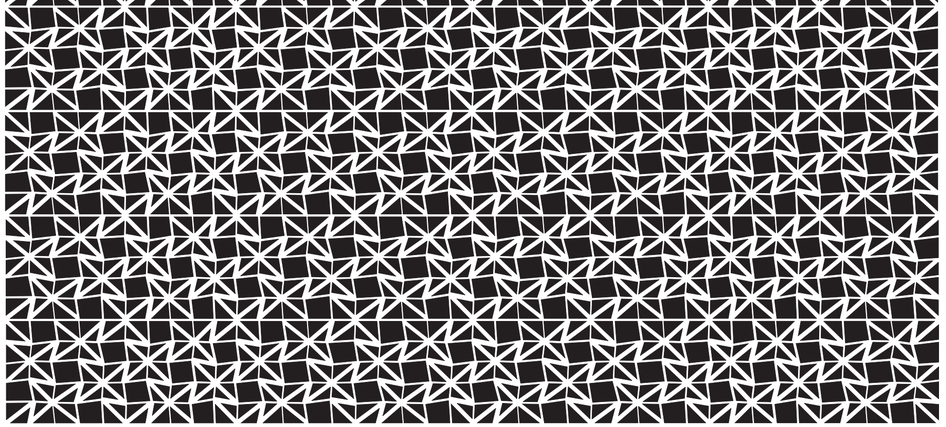
My Project in a Taxi

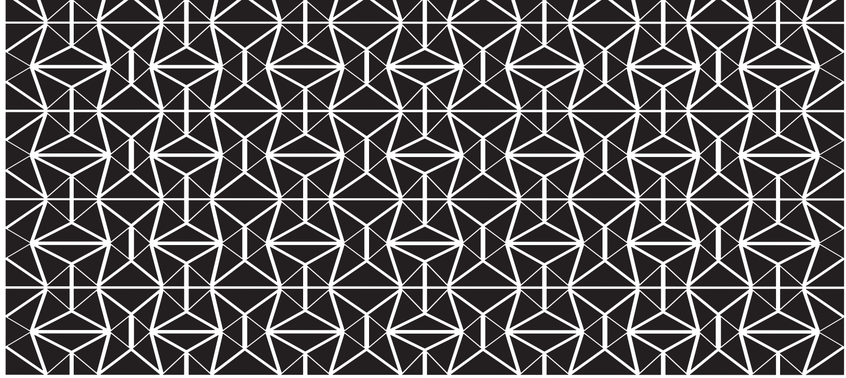
CONFIDENTIAL

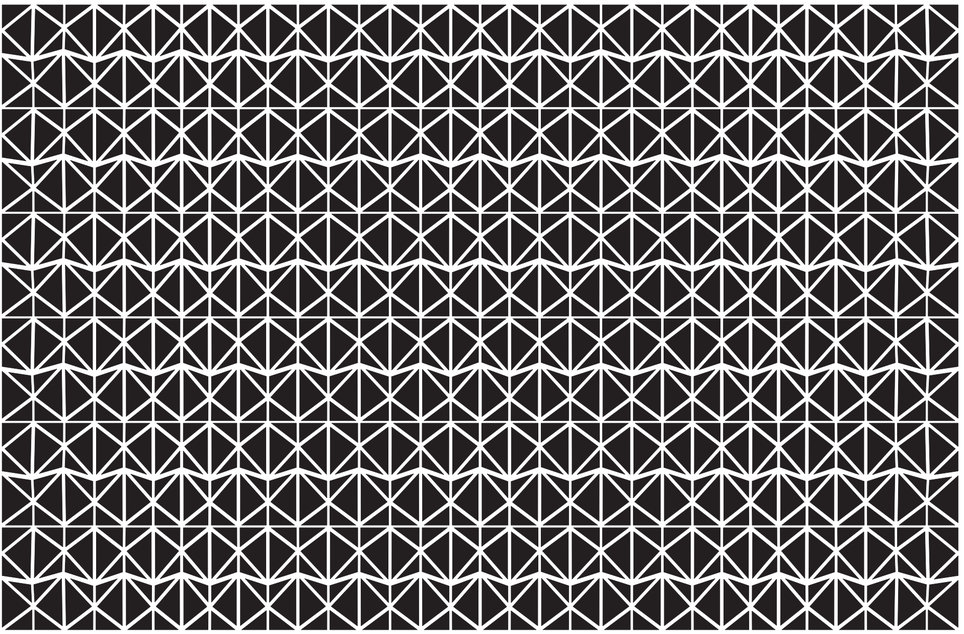
TYPE-X

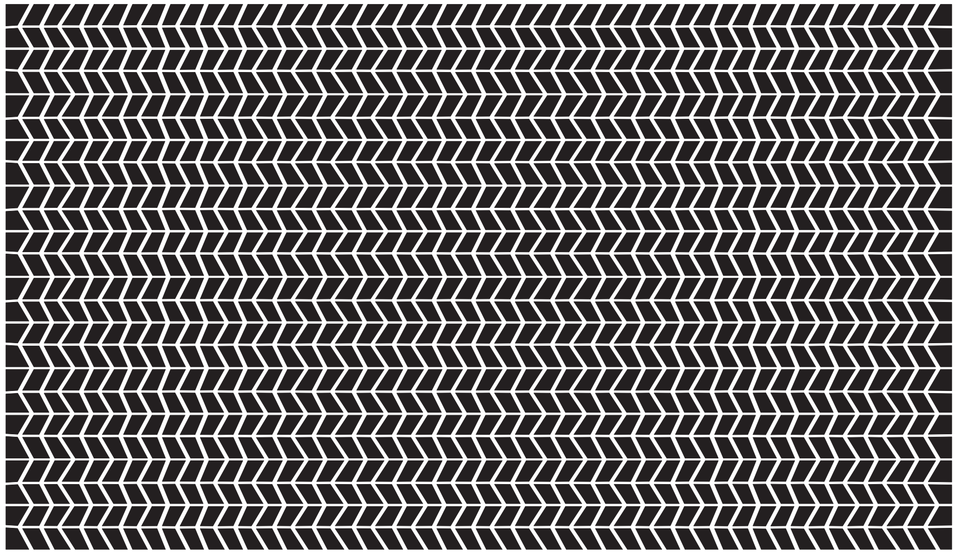
Inkjet 4D Print Project by A-POC ABLE ISSEY MIYAKE

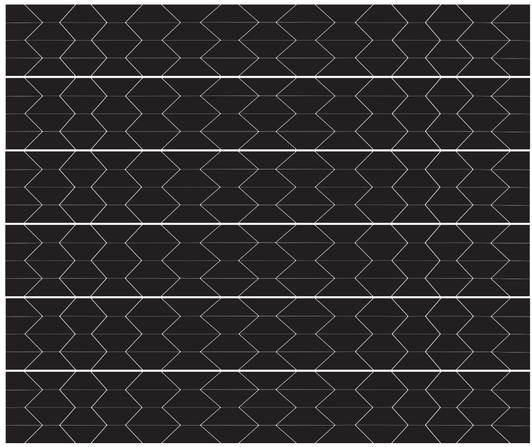


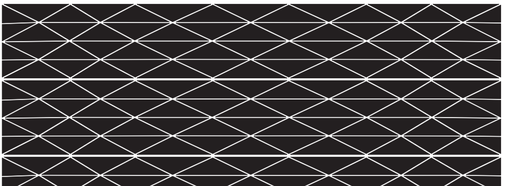


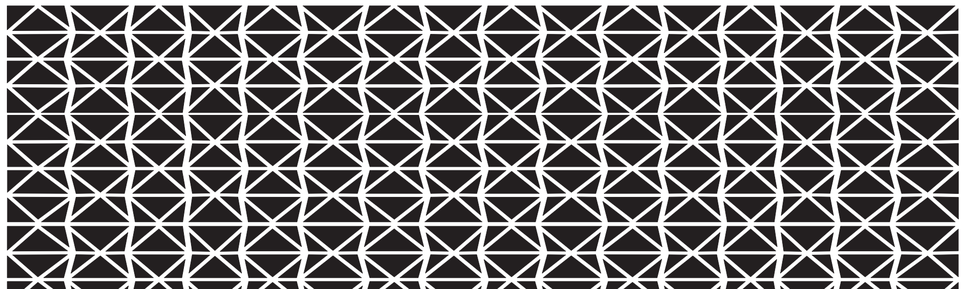


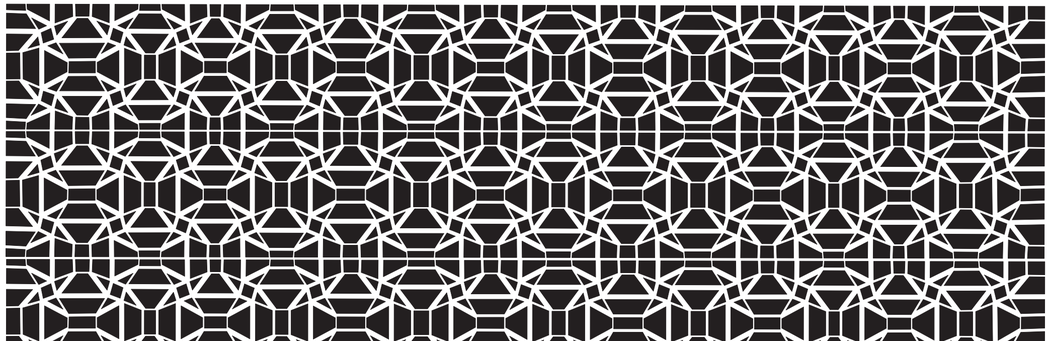






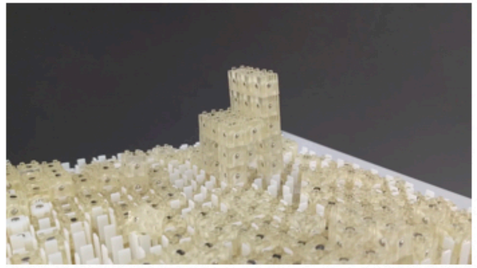




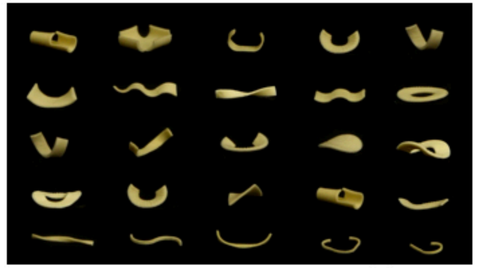


Other Projects

計算製造とマテリアル・インタラクションにまつわる他の研究

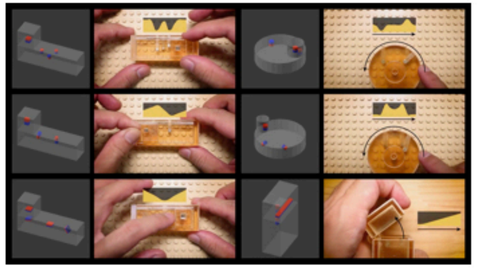


Dynablock

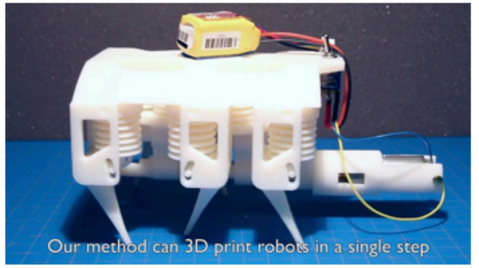


Morphlour

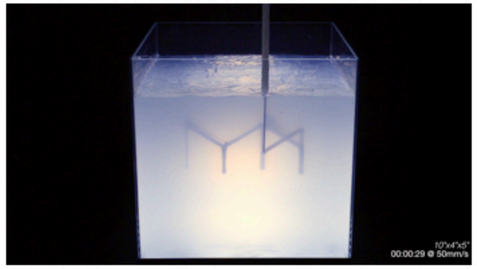
Metamaterial Mechanisms



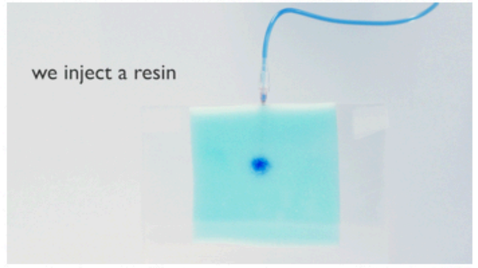
Magnetic Force Feedback



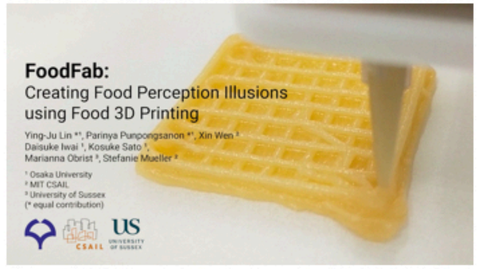
Printed Hydraulics



Rapid Liquid Printing

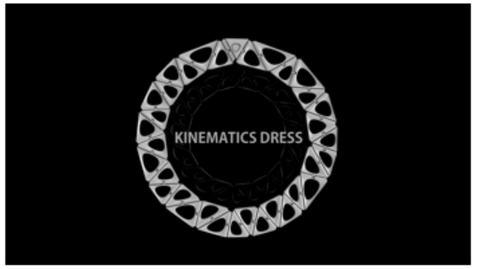


inFoam



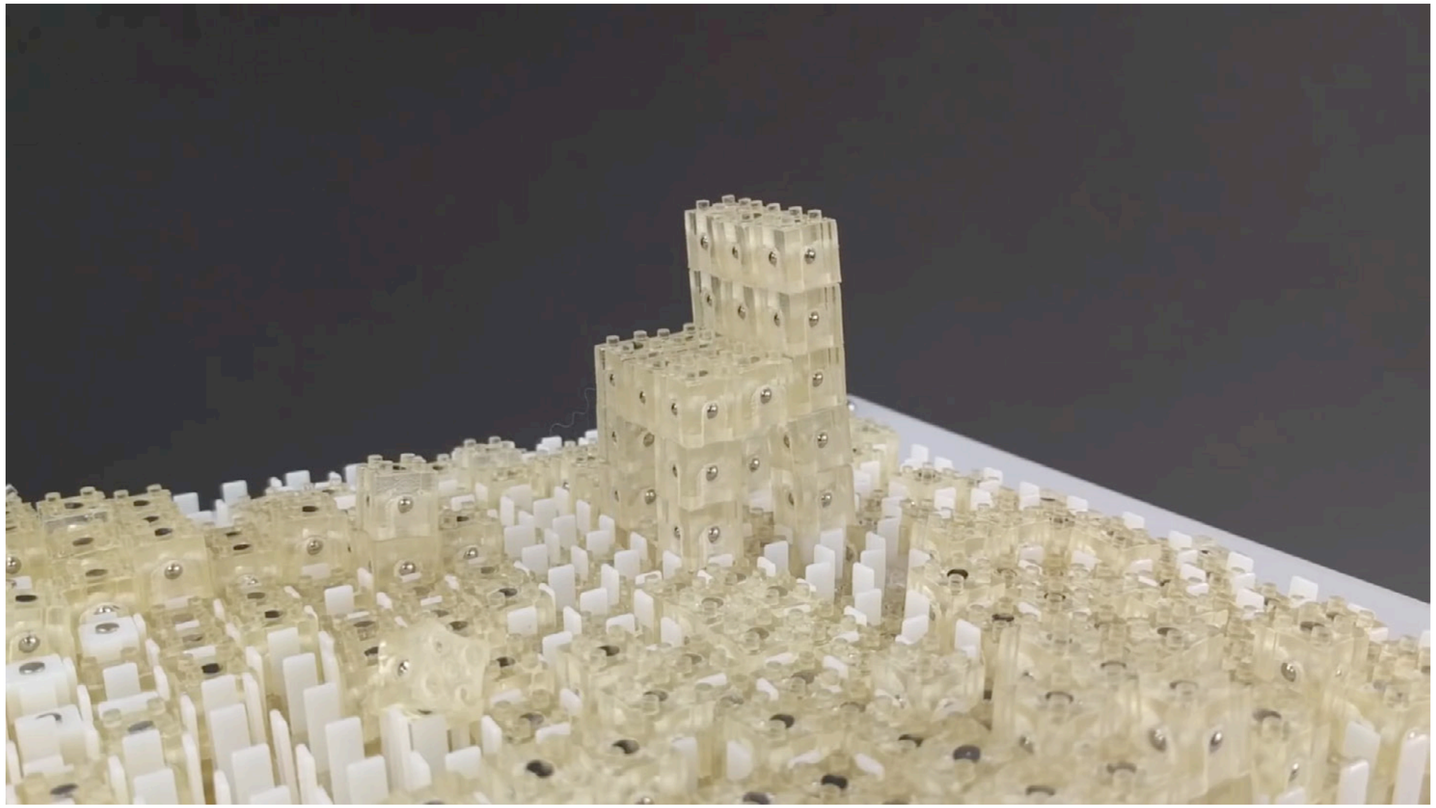
FoodFab

Shader Printer



Kinematic Dress

Dynablock



Rapid 3D printing by magnetic building blocks
Unused **structure** can go back to the **materials** again

Suzuki et al., Dynablock, UIST, 2018.

Morphlour

Morphing pasta by hydration / dehydration of flour
Computed shape is embedded into the structure

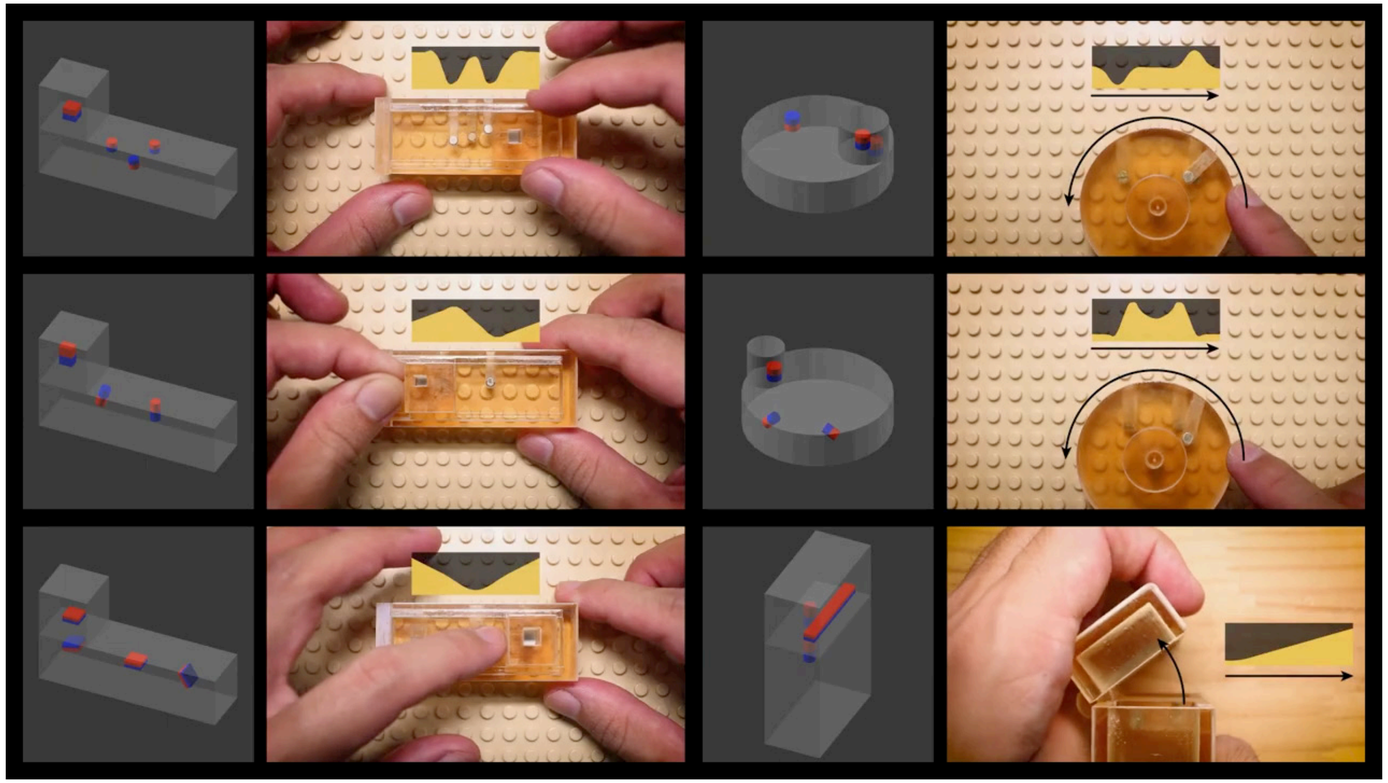
Tao et al., Morphlour, UIST2019.

Metamaterial Mechanisms

Design GUI for applying **mechanical metamaterials** for daily mechanisms
Motion is computed and embedded into the object

Ion et al., Metamaterial Mechanisms, UIST2016.

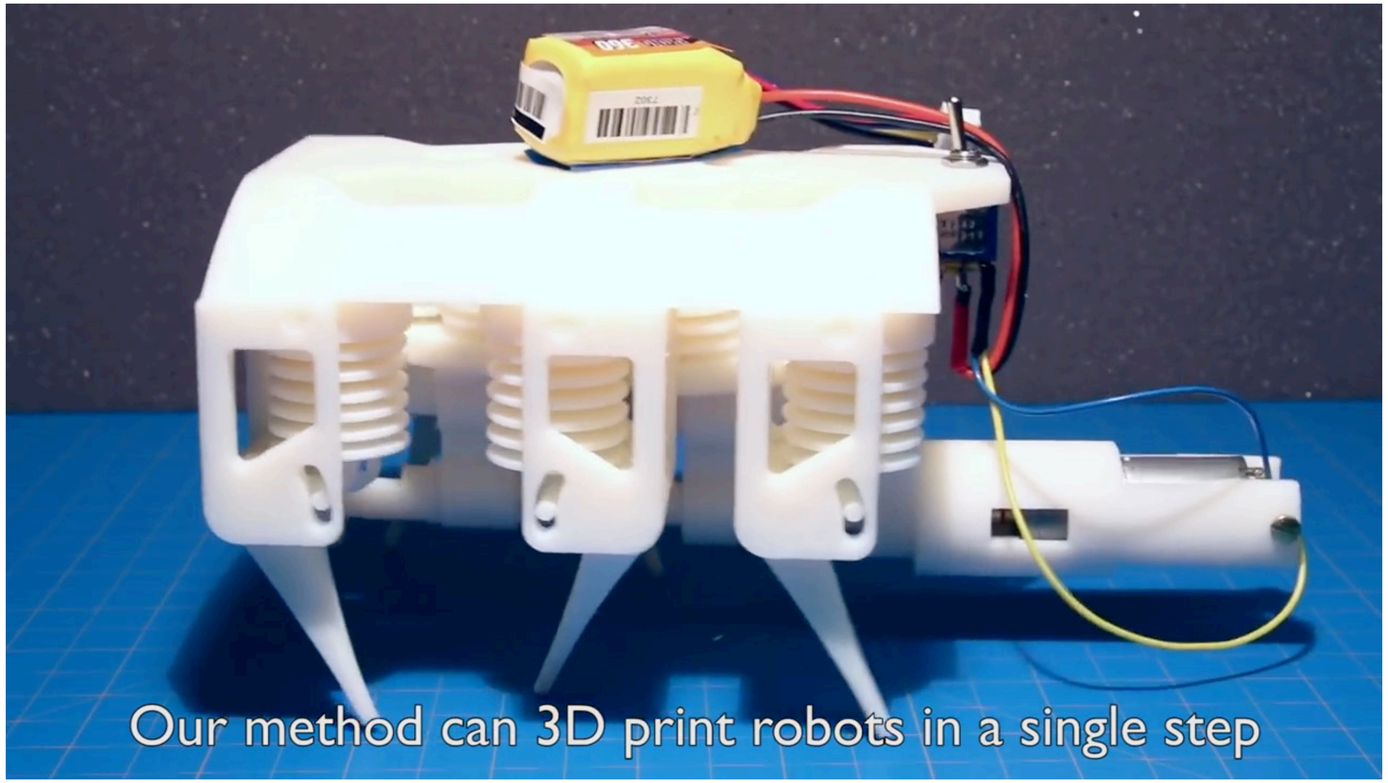
Magnetic Force Feedback Design



Inverse design and fabrication of **magnetic objects** with force feedback

Ogata et al., A Computational Approach to Magnetic Force Feedback Design CHI2021.

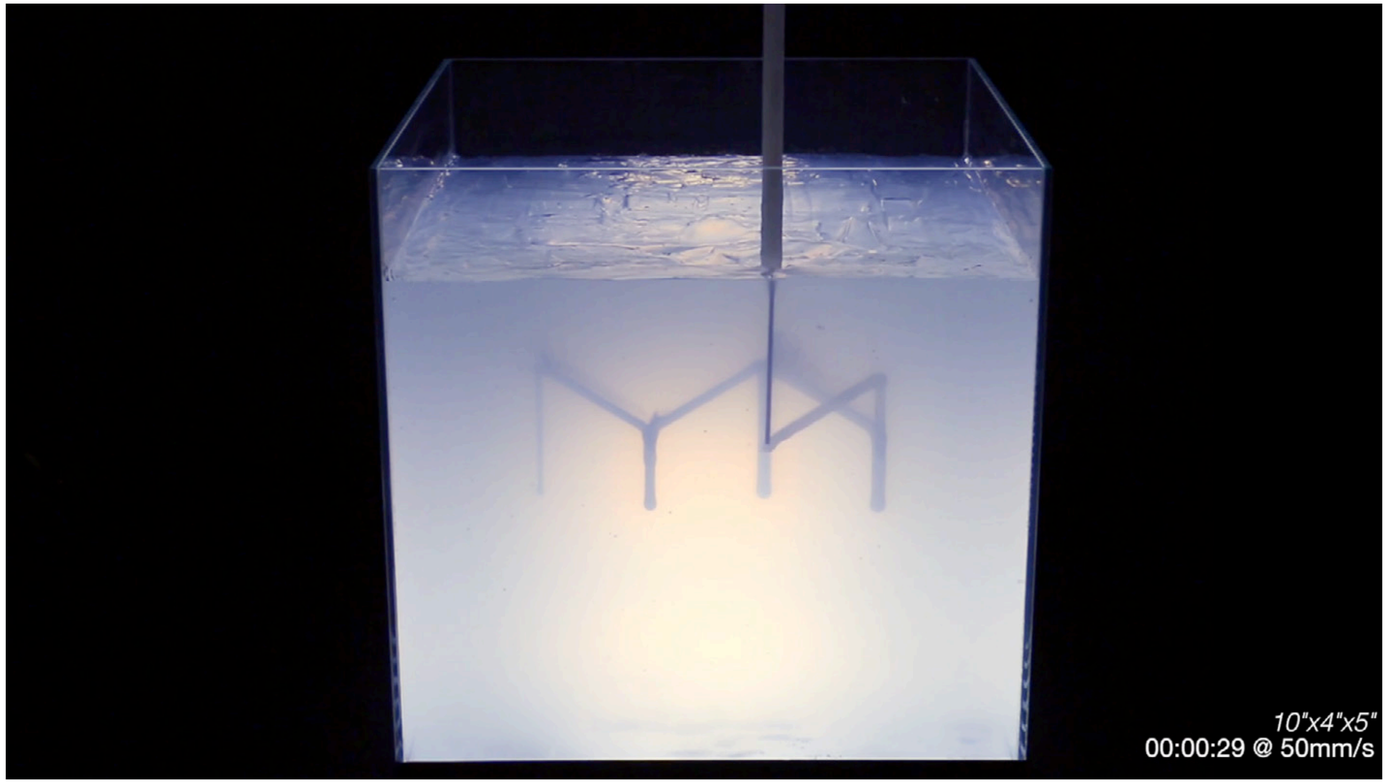
Printed Hydraulics



3D printing liquid to build a hydraulic robot **in a single step**

McCann et al., Printed Hydraulics, ICRA 2016.

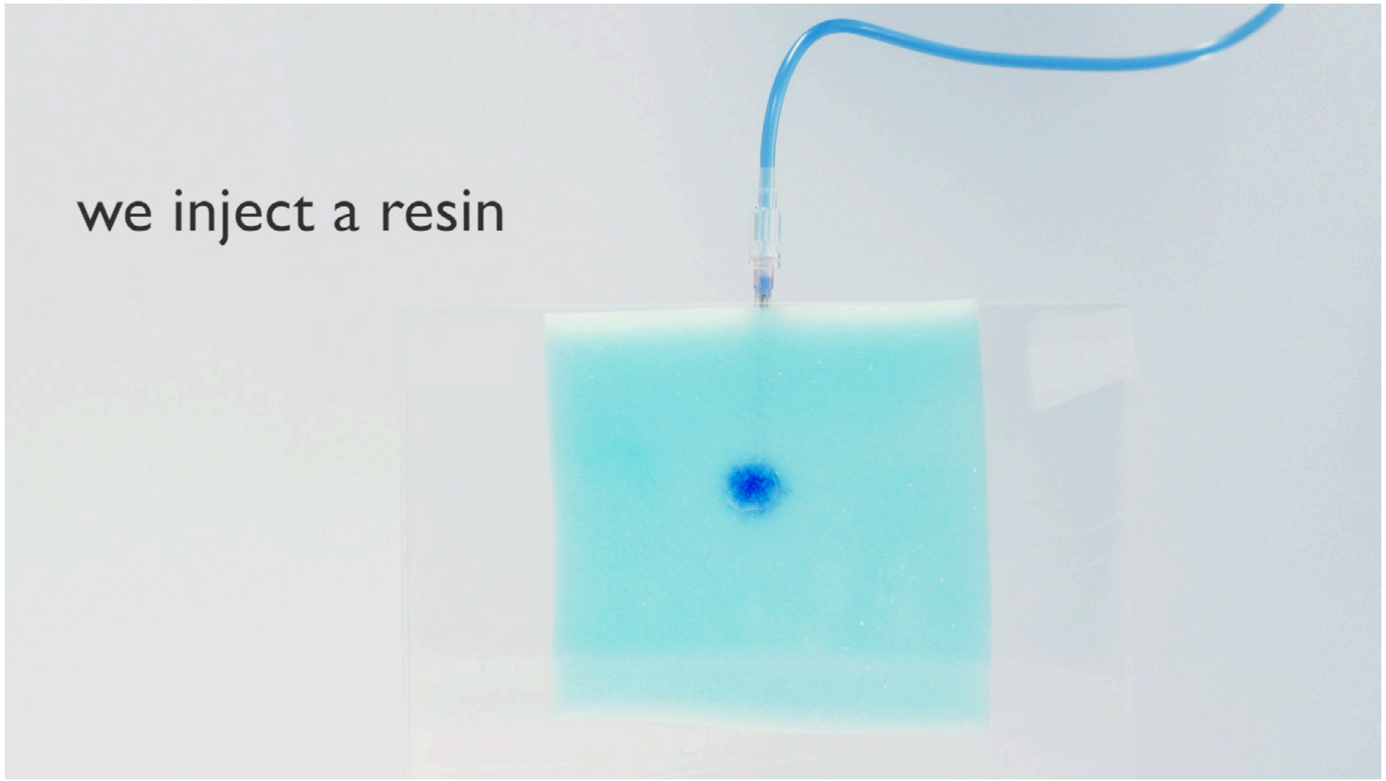
Rapid Liquid Printing



3D printing of large objects in **crushed gel suspension**

Self-assembly Lab, Rapid Liquid Printing, 2017

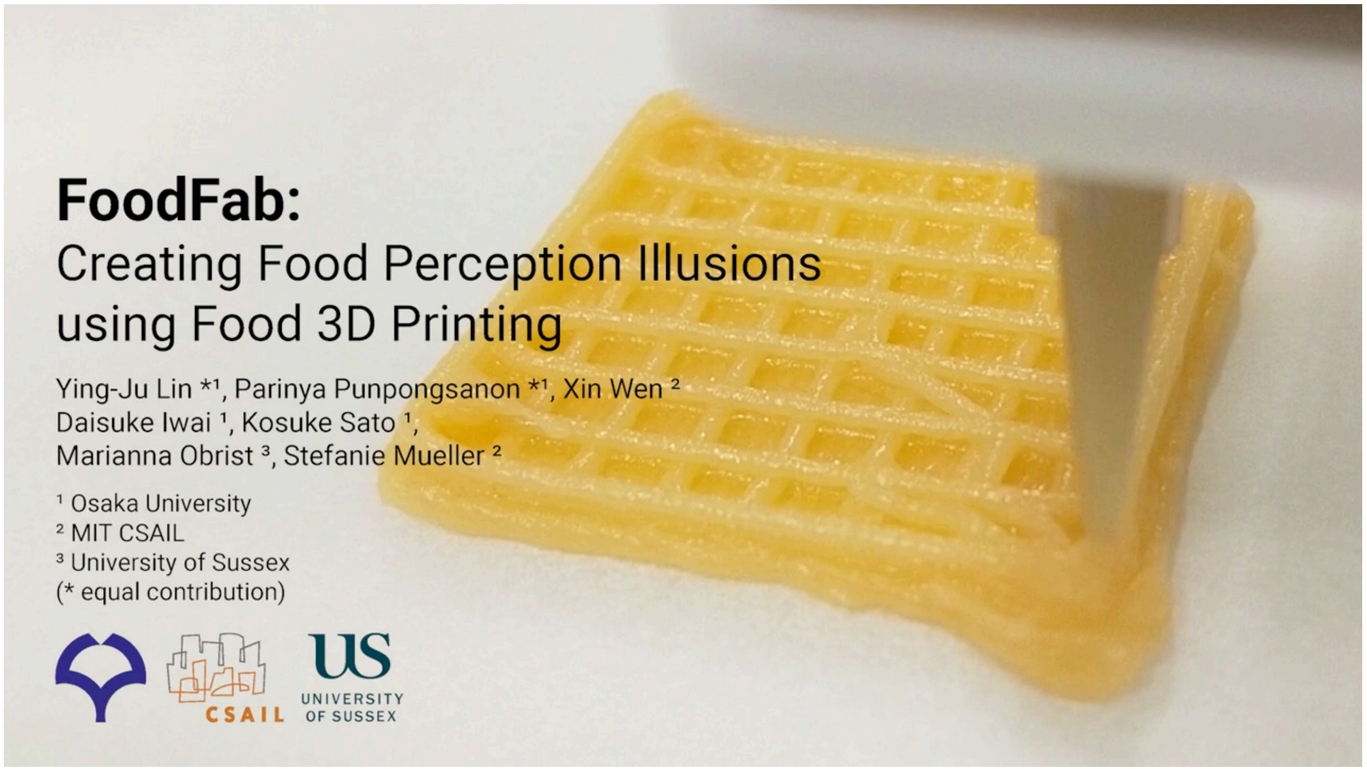
inFoam Printing



Injecting resin to a foam for controlled stiffness distribution

Clasen et al., inFoam Printing, 2017

FoodFab



Food printing with different texture for **satiety illusion**

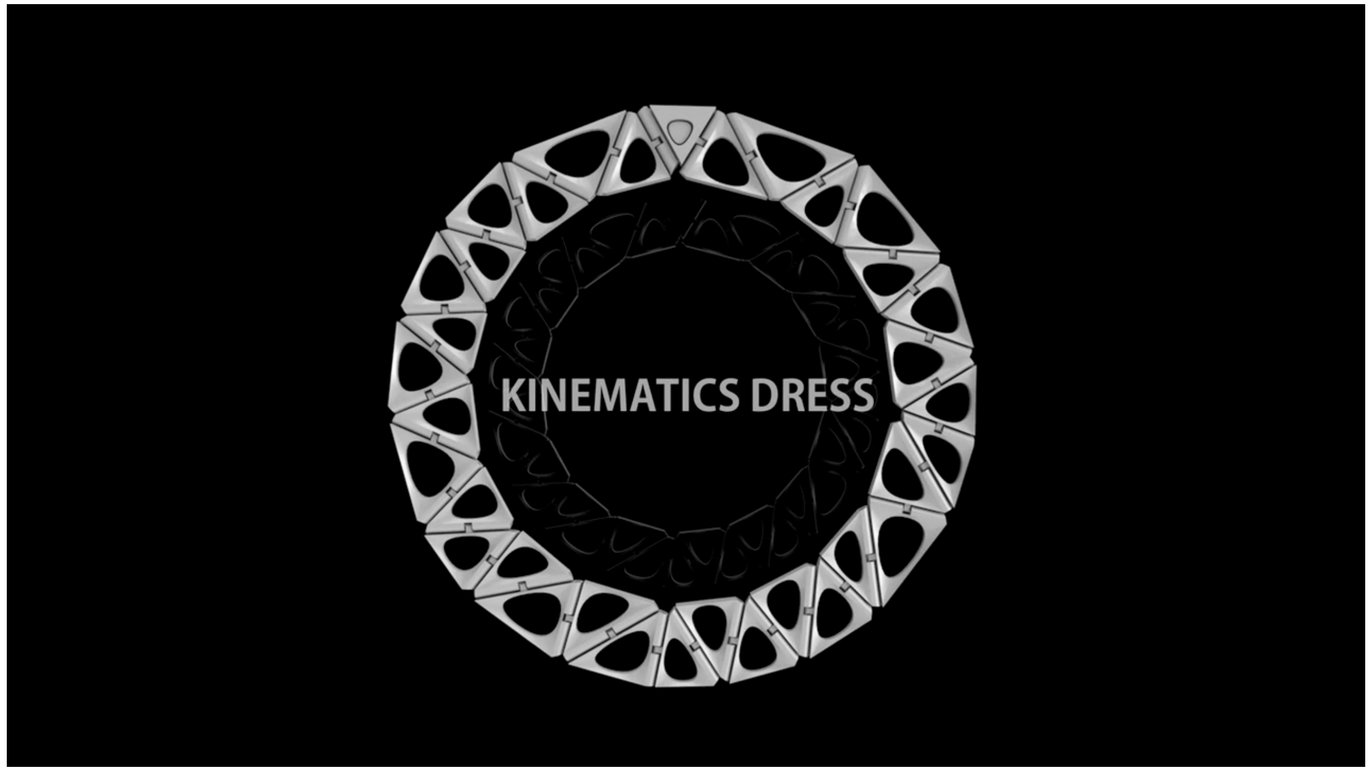
Lin et al., FoodFab, CHI 2020.

Shader Printer

Dynamically rendering a pattern with **bistable thermochromic ink** and **projection mapping**

Koizumi et al., Shader Printer, SIGGRAPH ETech 2012.

3D Printed Kinematics Dress



3D printed dress by the triangle mesh and mechanical hinges

Nervous System, Kinematics Dress by Nervous System - 3D Printed by Shapeways, 2015

Conclusion

まとめ

コンピュテーショナル・ファブリケーション：計算して特殊な素材と構造を持つモノを作る。モノを作れる装置を作る

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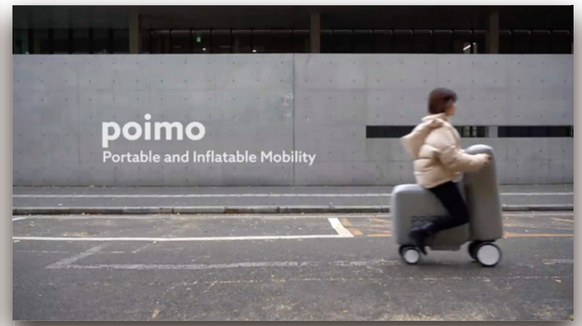
マテリアル・インタラクション：特殊な素材と構造で新たな体験を生み出す

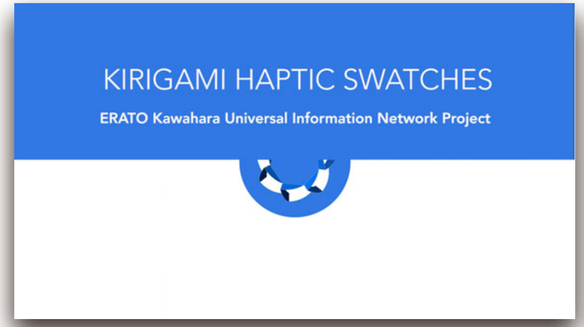
Liquid Pouch Motors
ICRA2017 + RoboSoft2020

Self-healing UI
UIST2019



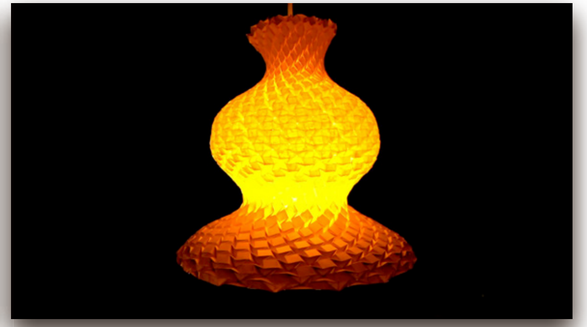
poimo
CHI EA 2020 & UIST2020

Pop-up Print
UIST2020



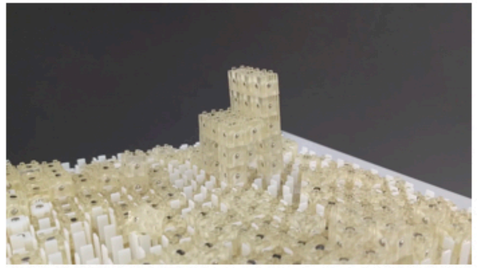
Kirigami Haptic Swatches
CHI2020

Flower Jelly Printer
CHI2021

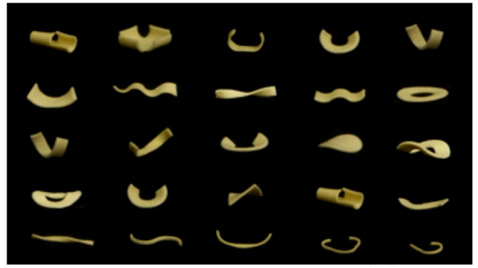


Crane
TOCHI (CHI2023)

Inkjet 4D Print
TOG (SIGGRAPH2023)

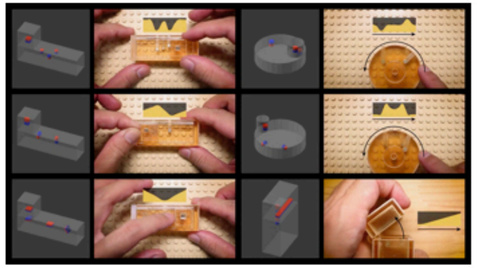


Dynablock

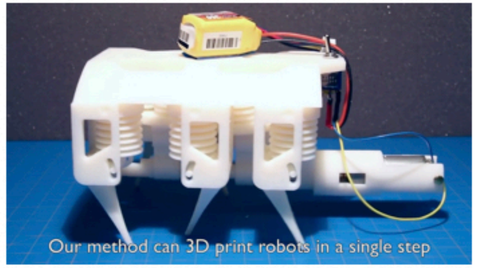


Morphlour

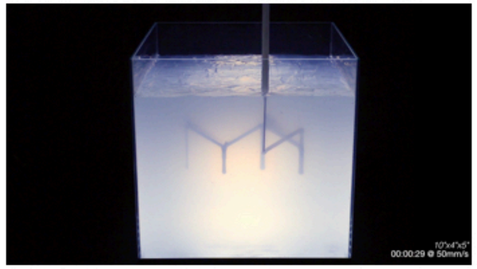
Metamaterial Mechanisms



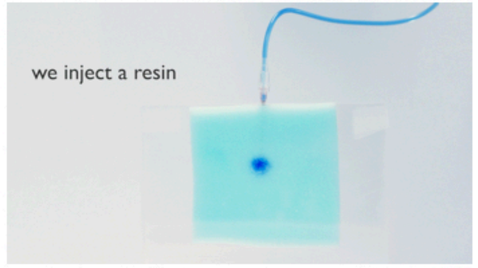
Magnetic Force Feedback



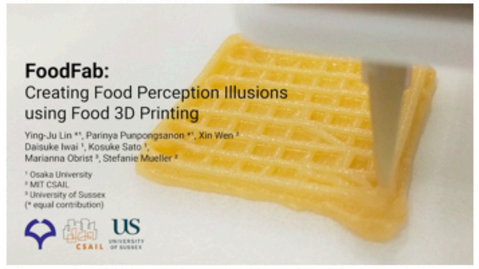
Printed Hydraulics



Rapid Liquid Printing



inFoam



FoodFab

Shader Printer

Kinematic Dress

コンピュテーショナル・ファブリケーション

素材（低沸点液体・自己修復素材・ドロップステッチファブリック・ゼリー）
構造（シート・インフレータブル・折紙）
設計（手描きの試作・GUI・逆問題の最適化）
製造（インクジェットプリンタ・各種3Dプリンタ・CNC）

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マテリアル・インタラクション

衣服
プロダクト
壁材
食品

Computational Fabrication x Material Interaction | Koya Narumi