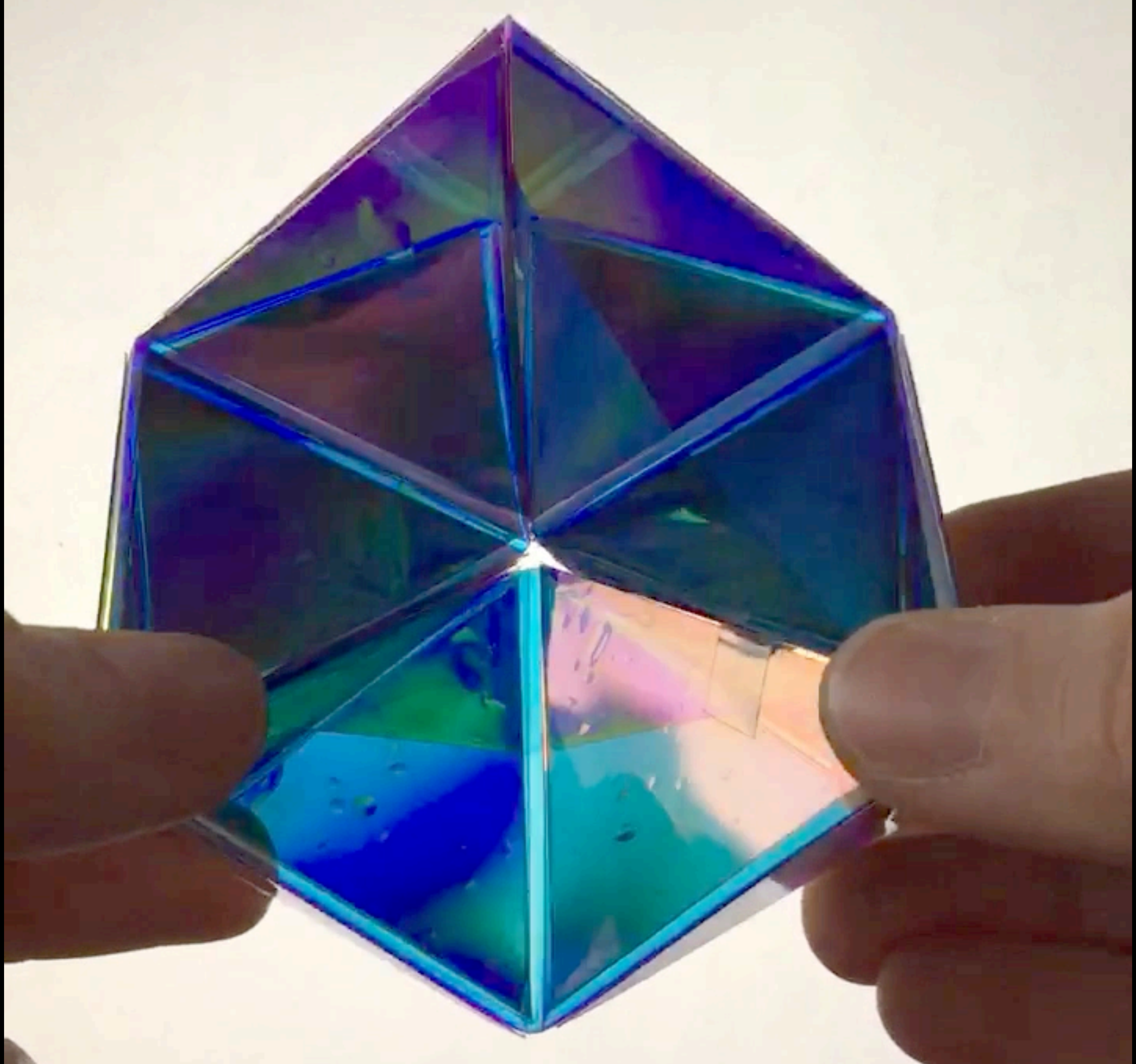
A WORKSHOP:
Understanding Topology through Origami

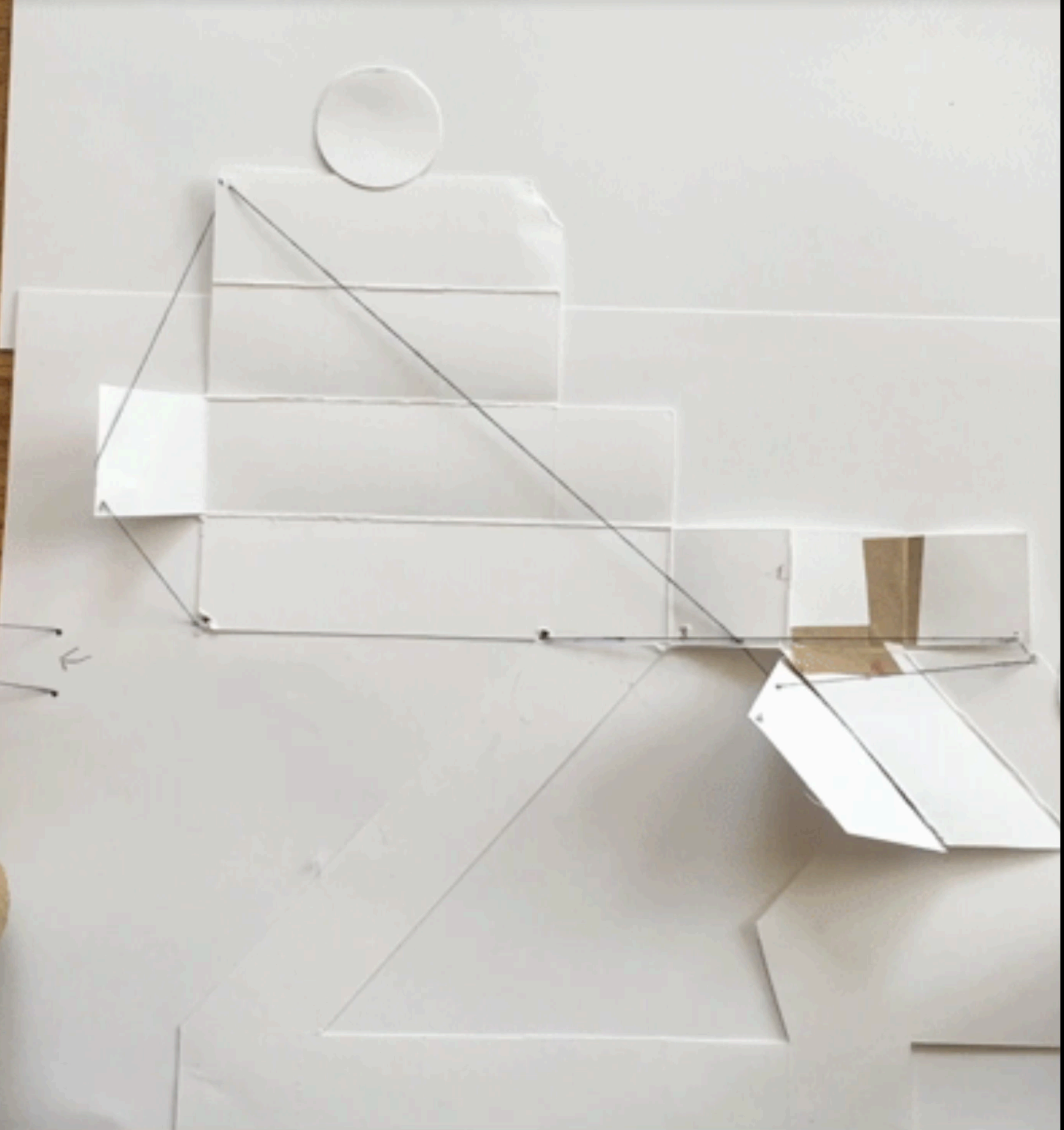
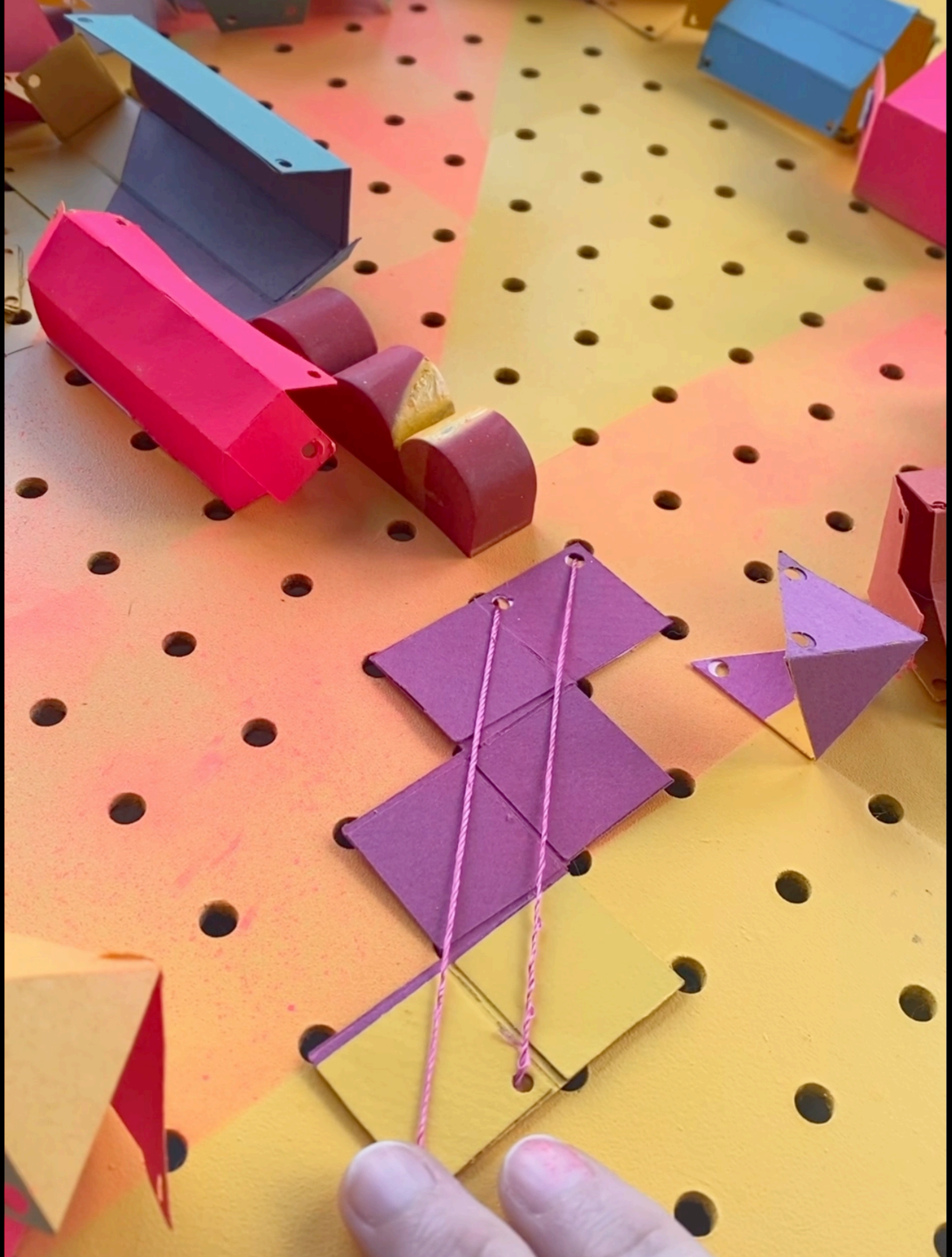
(While I give a talk about creating sensory inroads to abstract concepts)

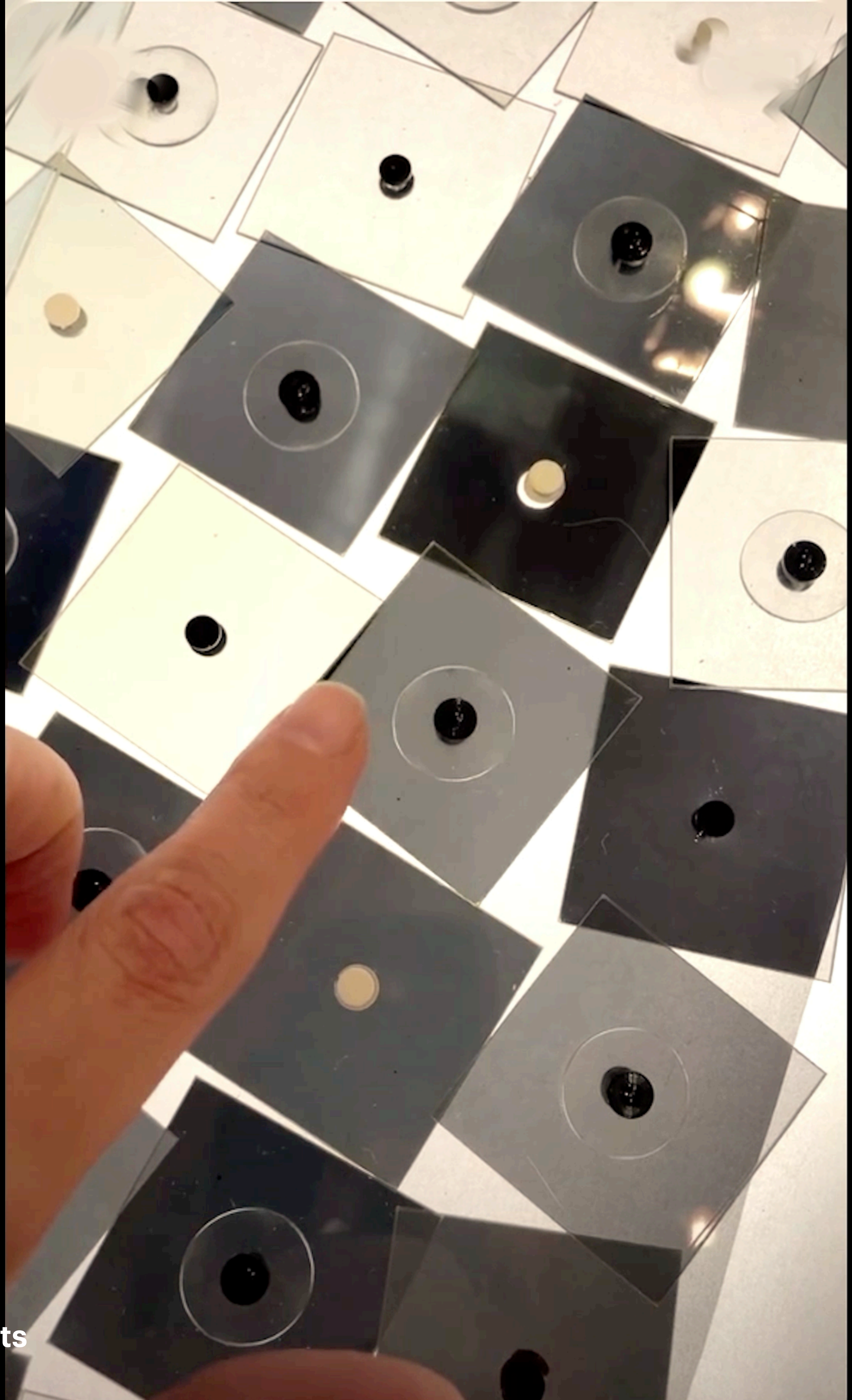
Kelli Anderson

Graphic Designer



Polarization filter experiment
(unpublished)



Antialiasing in Type
Installation at the Center for Book Arts

My “generative question”:

Why are lo-fi things still appealing in a world of advanced tech?

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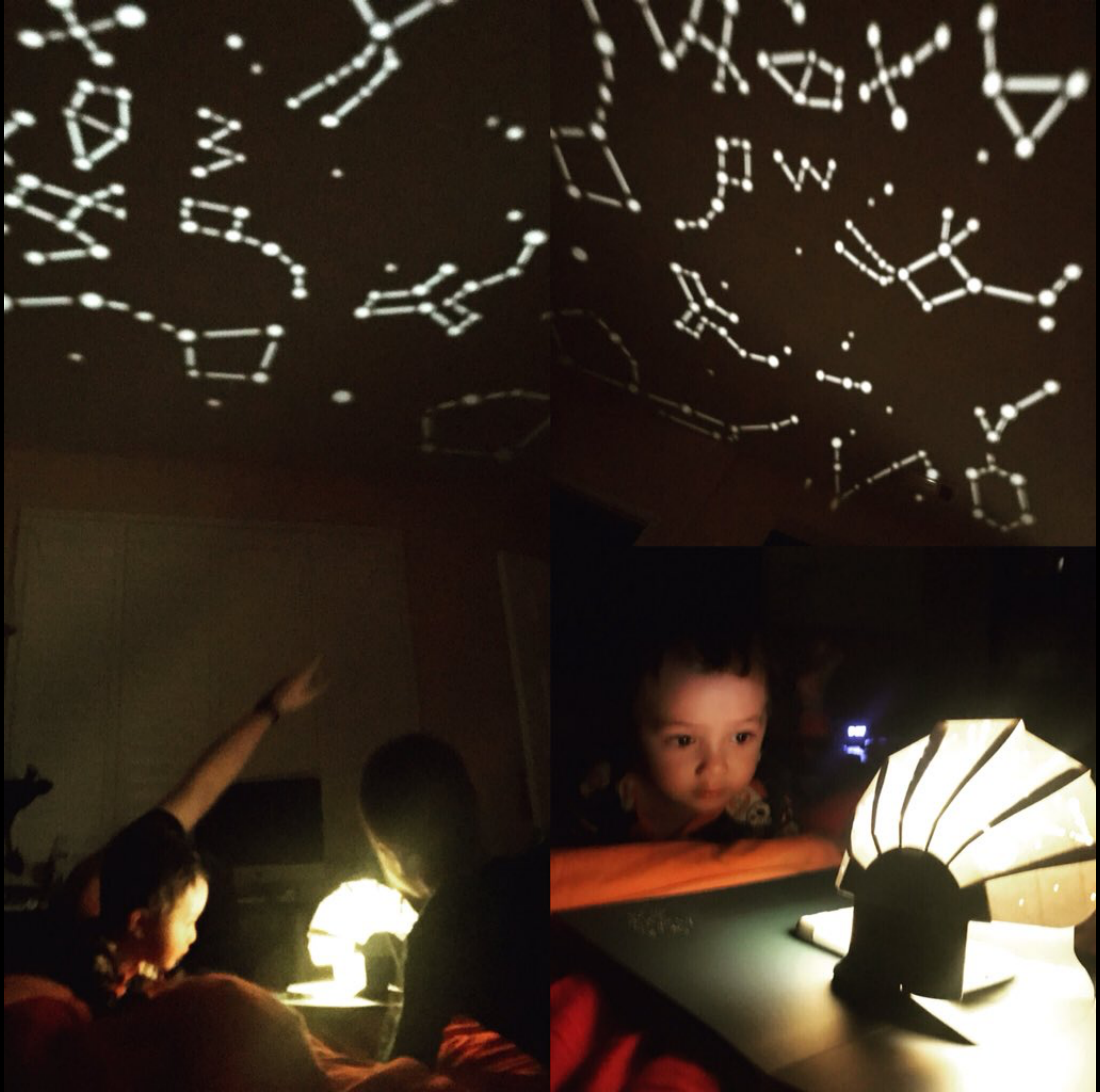
Why are lo-fi things still appealing in a world of advanced tech?

A working theory:

We think through our bodies. The flimsier the interface = the closer to the mysteries

This Book is a Planetarium,
Chronicle Books

This Book is a Planetarium,
Chronicle Books



This Book is a Planetarium,
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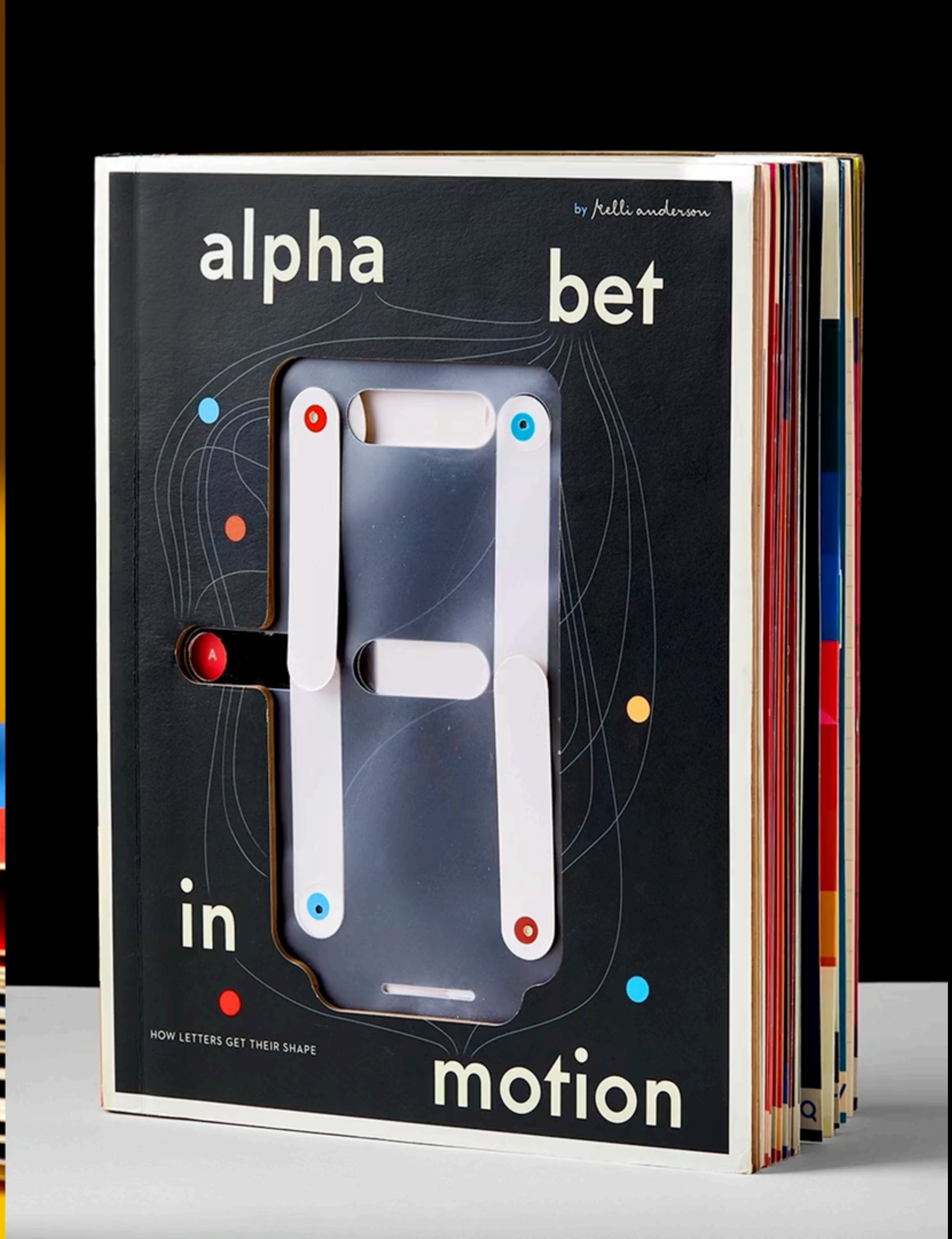

***Alphabet in Motion: How Letters Get Their Shape*,**
Katherine Small Gallery / Artbook

Alphabet in Motion: How Letters Get Their Shape,
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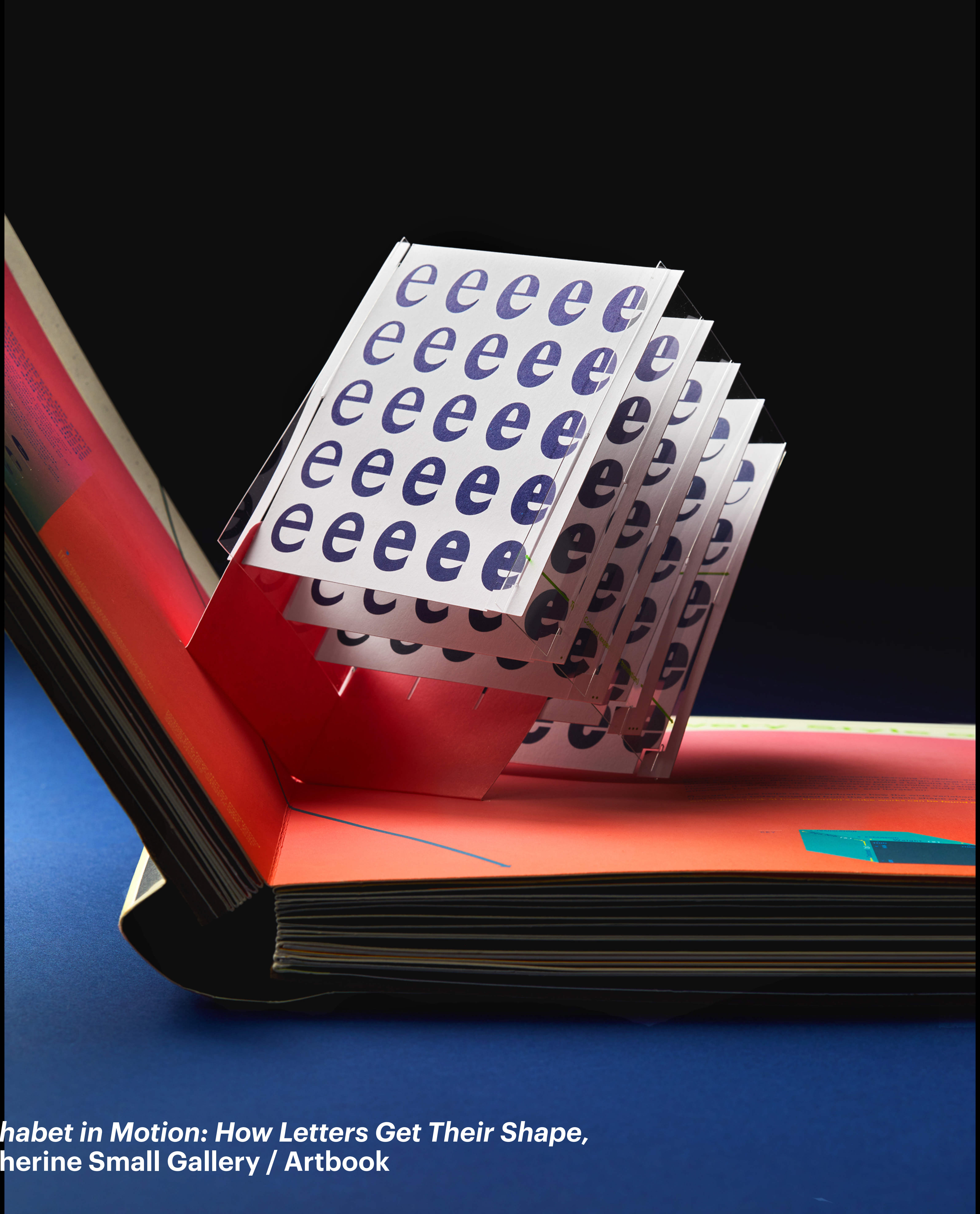
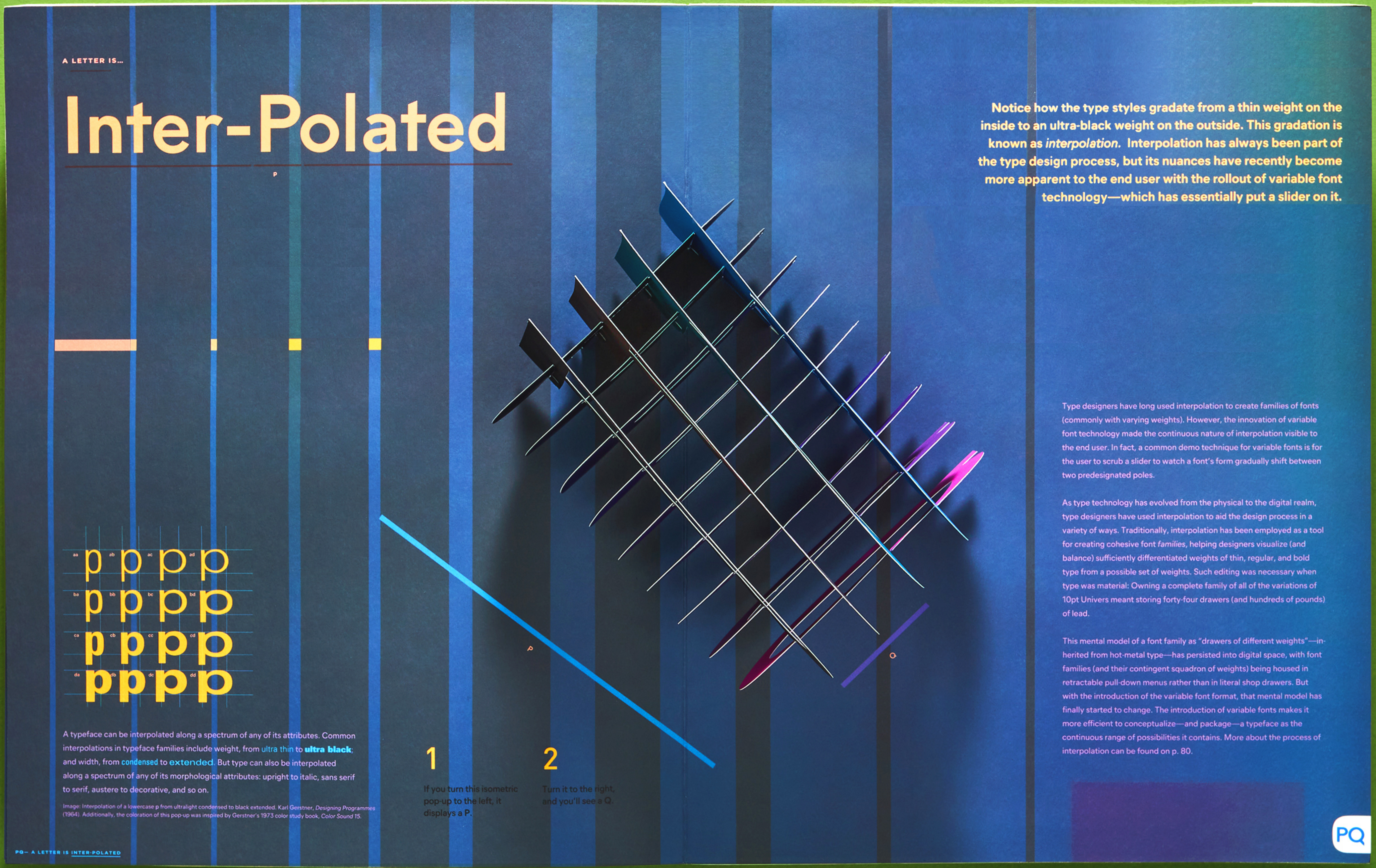


Alphabet in Motion: How Letters Get Their Shape,
Katherine Small Gallery / Artbook



A LETTER IS…

Inter-Polated

Notice how the type styles gradate from a thin weight on the inside to an ultra-black weight on the outside. This gradation is known as *interpolation*. Interpolation has always been part of the type design process, but its nuances have recently become more apparent to the end user with the rollout of variable font technology—which has essentially put a slider on it.

A typeface can be interpolated along a spectrum of any of its attributes. Common interpolations in typeface families include weight, from ultra thin to **ultra black**; and width, from condensed to extended. But type can also be interpolated along a spectrum of any of its morphological attributes: upright to italic, sans serif to serif, austere to decorative, and so on.

Image: Interpolation of a lowercase p from ultralight condensed to black extended. Karl Gerstner, *Designing Programmes* (1964). Additionally, the coloration of this pop-up was inspired by Gerstner's 1973 color study book, *Color Sound 15*.

1

If you turn this isometric pop-up to the left, it displays a P.

2

Turn it to the right, and you'll see a Q.

Type designers have long used interpolation to create families of fonts (commonly with varying weights). However, the innovation of variable font technology made the continuous nature of interpolation visible to the end user. In fact, a common demo technique for variable fonts is for the user to scrub a slider to watch a font's form gradually shift between two predesignated poles.

As type technology has evolved from the physical to the digital realm, type designers have used interpolation to aid the design process in a variety of ways. Traditionally, interpolation has been employed as a tool for creating cohesive font *families*, helping designers visualize (and balance) sufficiently differentiated weights of thin, regular, and bold type from a possible set of weights. Such editing was necessary when type was material: Owning a complete family of all of the variations of 10pt Univers meant storing forty-four drawers (and hundreds of pounds) of lead.

This mental model of a font family as "drawers of different weights"—inherited from hot-metal type—has persisted into digital space, with font families (and their contingent squadron of weights) being housed in retractable pull-down menus rather than in literal shop drawers. But with the introduction of the variable font format, that mental model has finally started to change. The introduction of variable fonts makes it more efficient to conceptualize—and package—a typeface as the continuous range of possibilities it contains. More about the process of interpolation can be found on p. 80.

***Alphabet in Motion: How Letters Get Their Shape,* Katherine Small Gallery / Artbook**

What is a circle?

What is a circle?

$$(x-a)^2 + (y-b)^2 = r^2.$$

What is a circle?

What is a circle?

西野嘉章編『ONE HUNDRED STONEWARES 百石譜』(東京大学出版会)より：固い石を回転させて、より柔らかい石をくり抜いたと想像される。写真／上田義彦

From *ONE HUNDRED STONEWARES edited by* Yoshiaki Nishino (University of Tokyo Press). The hole is presumed to have been made by rotating a hard stone against the softer stone. Photo by Yoshihiko Ueda.

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$$(x-a)^2+(y-b)^2=r^2.$$

Català
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Dansk
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Eesti
Español
Esperanto
Euskara
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Français
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Slovenčina
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Svenska
ไทย
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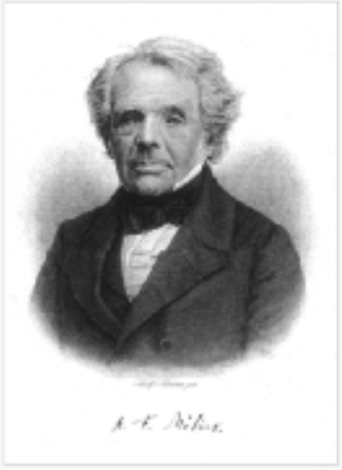
Edit links

Properties [edit]

The Möbius strip has several curious properties. A line drawn starting from the seam down the middle meets back at the seam but at the other side. If continued the line meets the starting point, and is double the length of the original strip. This single continuous curve demonstrates that the Möbius strip has only one boundary.



August Ferdinand Möbius

Cutting a Möbius strip along the center line with a pair of scissors yields one long strip with two full twists in it, rather than two separate strips; the result is not a Möbius strip. This happens because the original strip only has one edge that is twice as long as the original strip. Cutting creates a second independent edge, half of which was on each side of the scissors. Cutting this new, longer, strip down the middle creates two strips wound around each other, each with two full twists.

If the strip is cut along about a third of the way in from the edge, it creates two strips: One is a thinner Möbius strip – it is the center third of the original strip, comprising 1/3 of the width and the same length as the original strip. The other is a longer but thin strip with two full twists in it – this is a neighborhood of the edge of the original strip, and it comprises 1/3 of the width and twice the length of the original strip.

Other analogous strips can be obtained by similarly joining strips with two or more half-twists in them instead of one. For example, a strip with three half-twists, when divided lengthwise, becomes a strip tied in a trefoil knot. (If this knot is unravelled, the strip is made with eight half-twists in addition to an overhand knot.) A strip with N half-twists, when bisected, becomes a strip with $N+1$ full twists. Giving it extra twists and reconnecting the ends produces figures called paradromic rings.

Geometry and topology [edit]

One way to represent the Möbius strip as a subset of three-dimensional Euclidean space is using the parametrization:

$$x(u,v) = \left(1 + \frac{v}{2}\cos\frac{u}{2}\right)\cos u$$

$$y(u,v) = \left(1 + \frac{v}{2}\cos\frac{u}{2}\right)\sin u$$

$$z(u,v) = \frac{v}{2}\sin\frac{u}{2}$$

where $0 \le u < 2\pi$ and $-1 \le v \le 1$. This creates a Möbius strip of width 1 whose center circle has radius 1, lies in the xy plane and is centered at (0, 0, 0). The parameter u runs around the strip while v moves from one edge to the other.

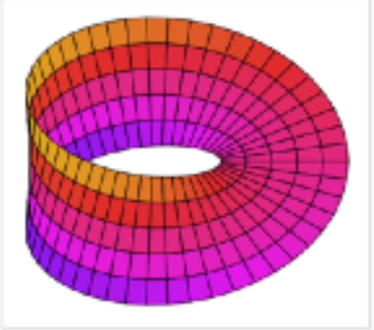
A ray-traced parametric plot of a Möbius strip

In cylindrical polar coordinates (r, θ, z), an unbounded version of the Möbius strip can be represented by the equation:

$$\log(r)\sin\left(\frac{1}{2}\theta\right) = z\cos\left(\frac{1}{2}\theta\right).$$

Widest isometric embedding in 3-space [edit]

If a smooth Möbius strip in 3-space is a rectangular one – that is, created from identifying two opposite sides of a geometrical rectangle with bending but not stretching the surface – then such an embedding is known to be possible if the aspect ratio of the rectangle is greater than the square root of 3. (Note that it is the shorter sides of the rectangle that are identified to obtain the Möbius strip.) For an aspect ratio less than or equal to the square root of 3, however, a smooth embedding of a rectangular Möbius strip into 3-space may be impossible.

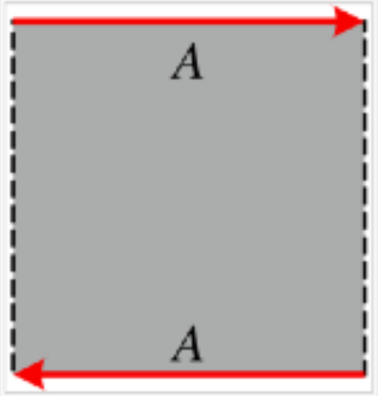


A parametric plot of a Möbius strip

As the aspect ratio approaches the limiting ratio of $\sqrt{3}$ from above, any such rectangular Möbius strip in 3-space seems to approach a shape that in the limit can be thought of as a strip of three equilateral triangles, folded on top of one another so that they occupy just one equilateral triangle in 3-space.

If the Möbius strip in 3-space is only once continuously differentiable (in symbols: C^1), however, then the theorem of Nash-Kuiper shows that there is no lower bound.

A method of making a Möbius strip from a rectangular strip too wide to simply twist and join (e.g., a rectangle only 1 unit long and 1 unit wide) is to first fold the wide direction back and forth using an even number of folds—an *accordion fold*—so that the folded strip becomes narrow enough that it can be twisted and joined, much as a single long-enough strip can be joined.[5] With two folds, for example, a 1 × 1 strip would become a 1 × ⅓ folded strip whose cross section is in the shape of an 'N' and would remain an 'N' after a half-twist. This folded strip, three times as long as it is wide, would be long enough to then join at the ends. This method works in principle but becomes impractical after sufficiently many folds, if paper is used. Using normal paper, this construction can be folded flat, with all the layers of the paper in a single plane. But mathematically, it is not clear whether this is possible without stretching the surface of the rectangle.[6]



To turn a rectangle into a Möbius strip, join the edges labelled *A* so that the directions of the arrows match.

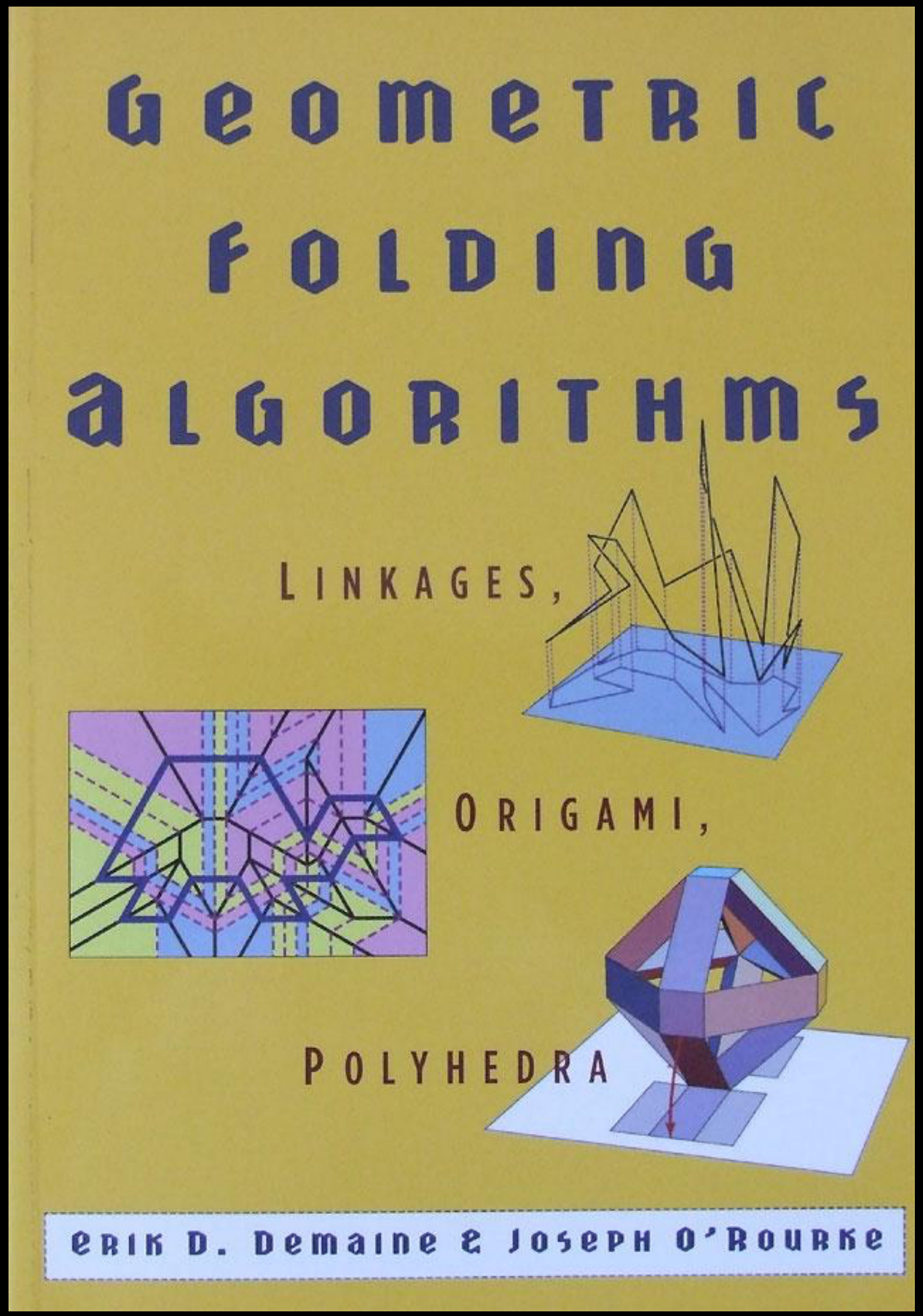
Topology [edit]

Topologically, the Möbius strip can be defined as the square [0, 1] × [0, 1] with its top and bottom sides identified by the relation $(x, 0) \sim (1 - x, 1)$ for $0 \le x \le 1$, as in the diagram on the right.

A less used presentation of the Möbius strip is as the topological quotient of a torus.[7] A torus can be constructed as the square [0, 1] × [0, 1] with the edges identified as $(0, y) \sim (1, y)$ (glue left to right) and $(x, 0) \sim (x, 1)$ (glue bottom to top). If one then also identified $(x, y) \sim (y, x)$, then one obtains the Möbius strip. The diagonal of the square (the points (x, x) where both coordinates agree) becomes the boundary of the Möbius strip, and carries an orbifold structure, which geometrically corresponds to "reflection" – geodesics (straight lines) in the Möbius strip reflect off the edge back into the strip. Notationally, this is written as T^2/S_2 – the 2-torus quotiented by the group action of the symmetric group on two letters (switching coordinates), and it can be thought of as the configuration space of two unordered points on the circle, possibly the same (the edge corresponds to the points being the same), with the torus corresponding to two ordered points on the circle.

The Möbius strip is a two-dimensional compact manifold (i.e. a surface) with boundary. It is a standard example of a surface that is not orientable. In fact, the Möbius strip is the epitome of the topological phenomenon of nonorientability. This is because 1) two-dimensional shapes (surfaces) are the lowest-dimensional shapes for which nonorientability is possible, and 2) the Möbius strip is the **only** surface that is topologically a subspace of **every** non-orientable surface. As a result, any surface is non-orientable if and only if it contains a Möbius band as a subspace.

The Möbius strip is also a standard example used to illustrate the mathematical concept of a fiber bundle. Specifically, it is a nontrivial bundle over the circle S^1 with a fiber the unit interval, $I = [0, 1]$. Looking only at the edge of the Möbius strip gives a nontrivial two point (or Z_2) bundle over S^1.


Geometric
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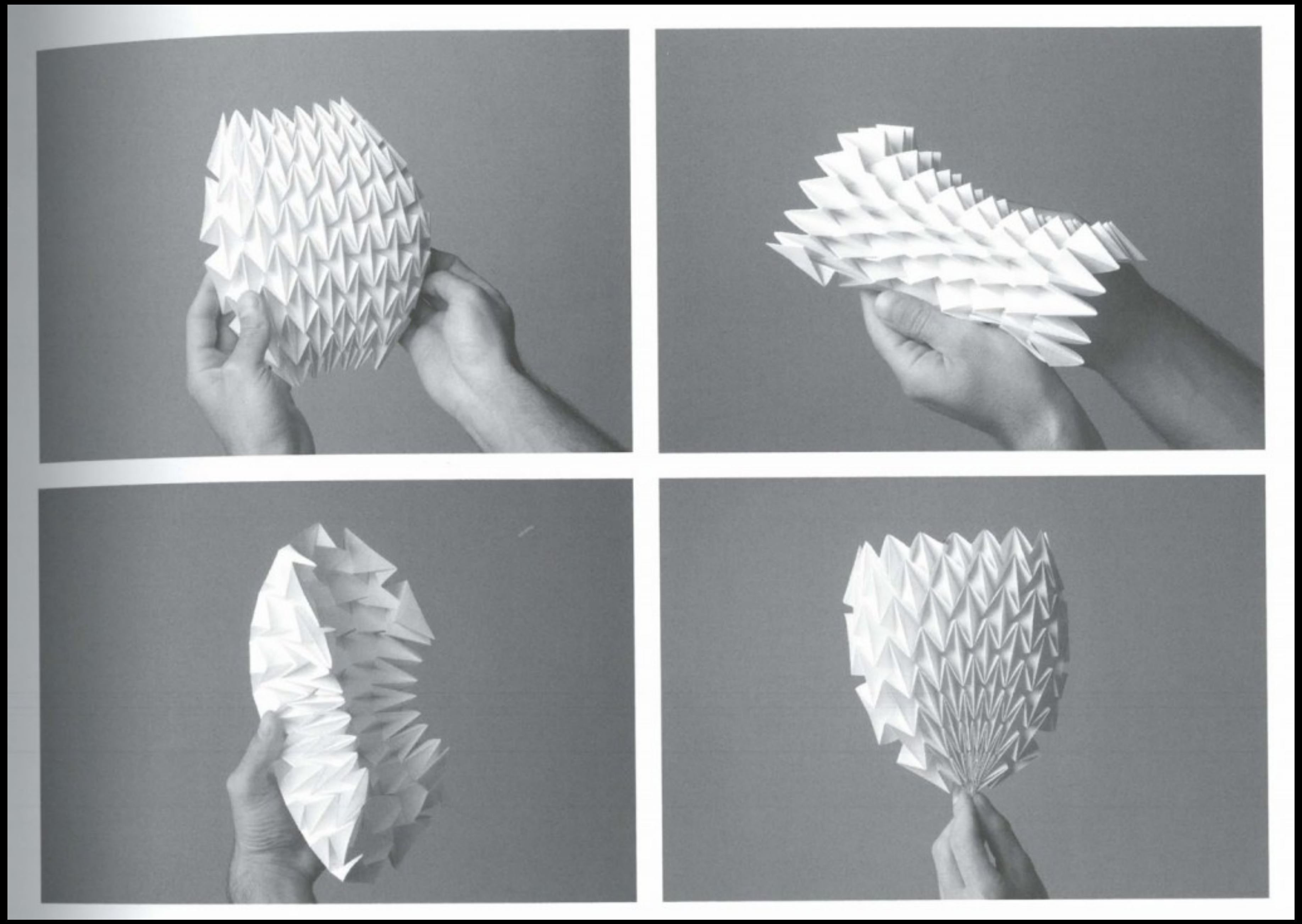
Linkages,
Origami,
Polyhedra
Erik D. Demaine & Joseph O'Rourke



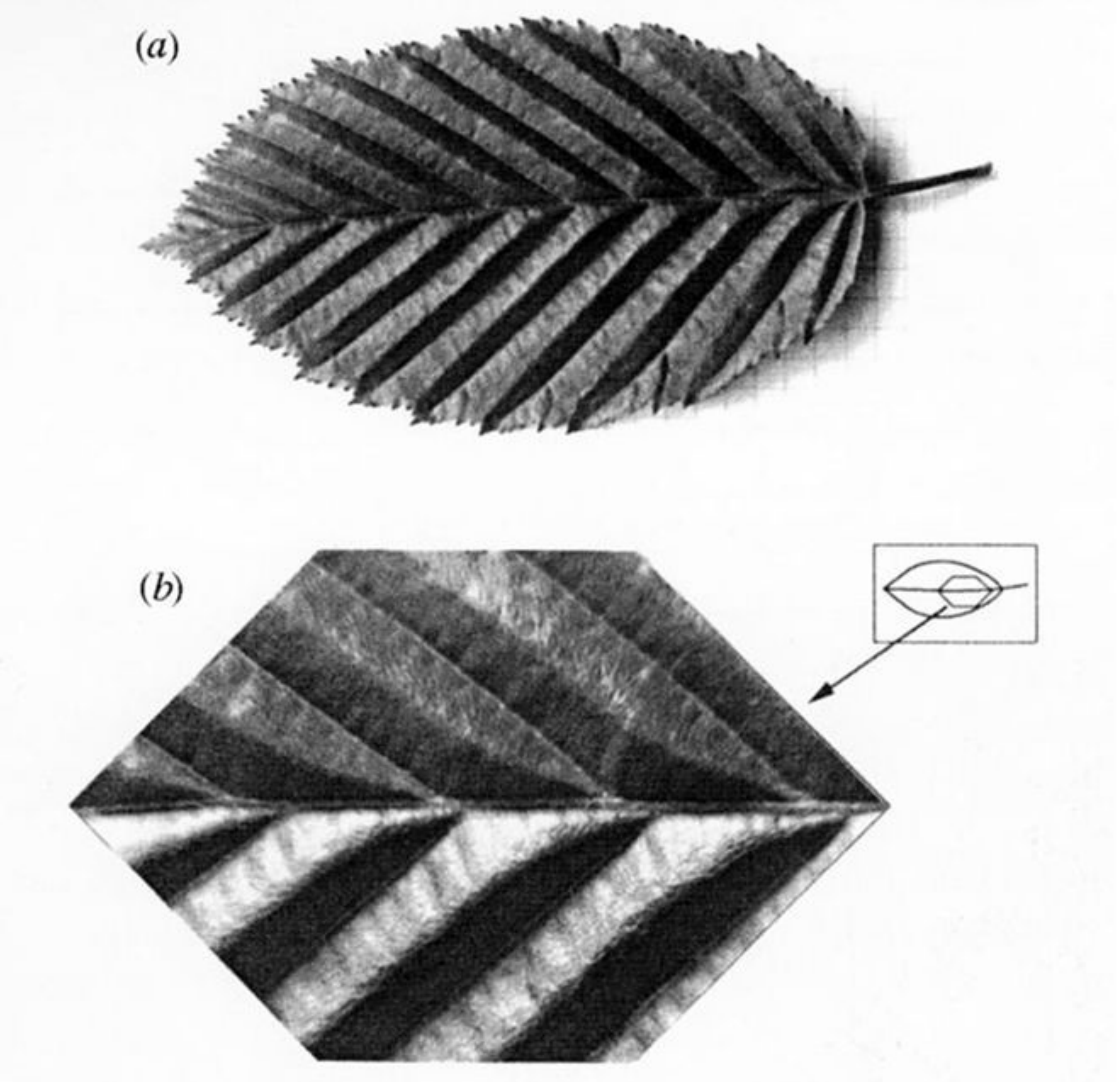
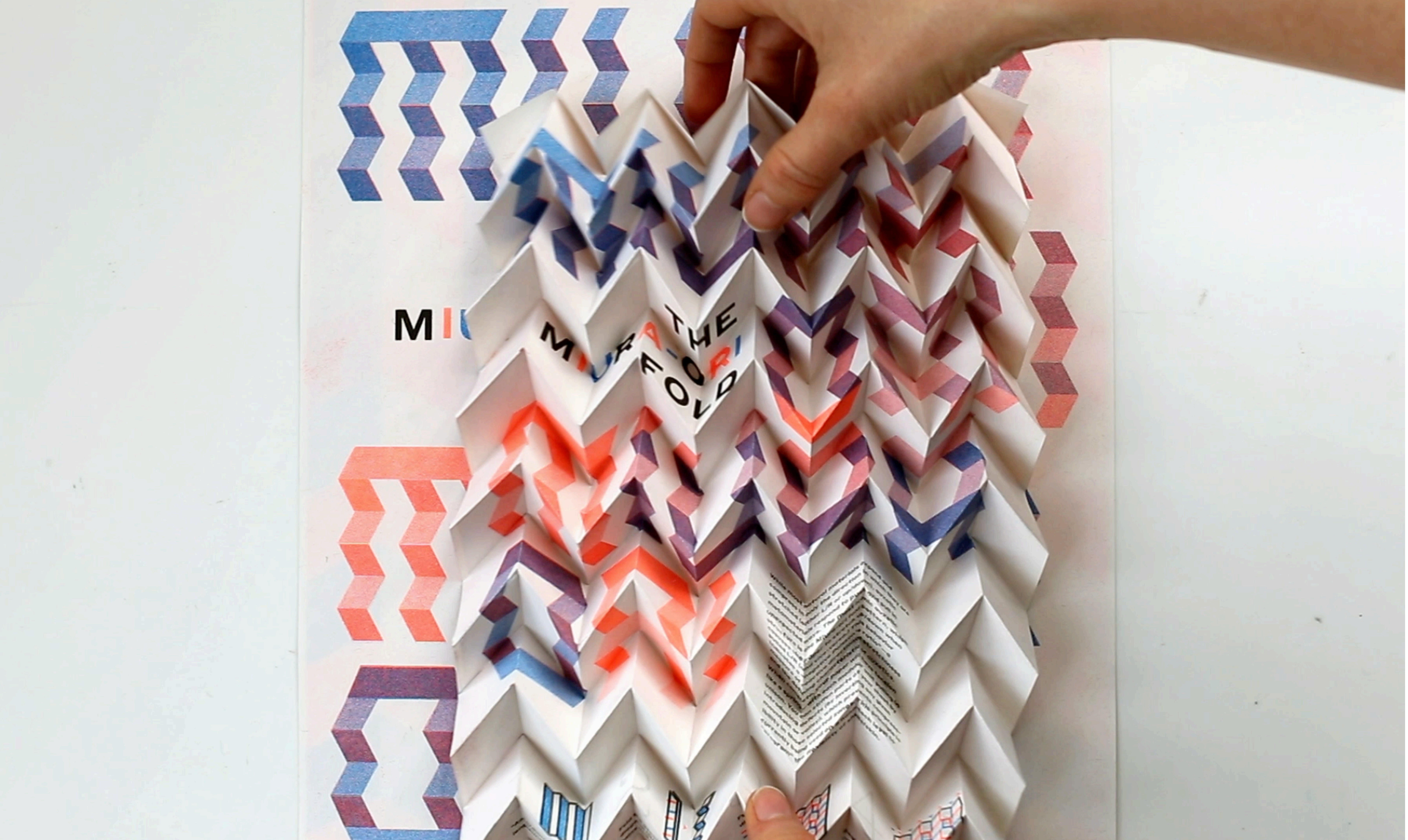
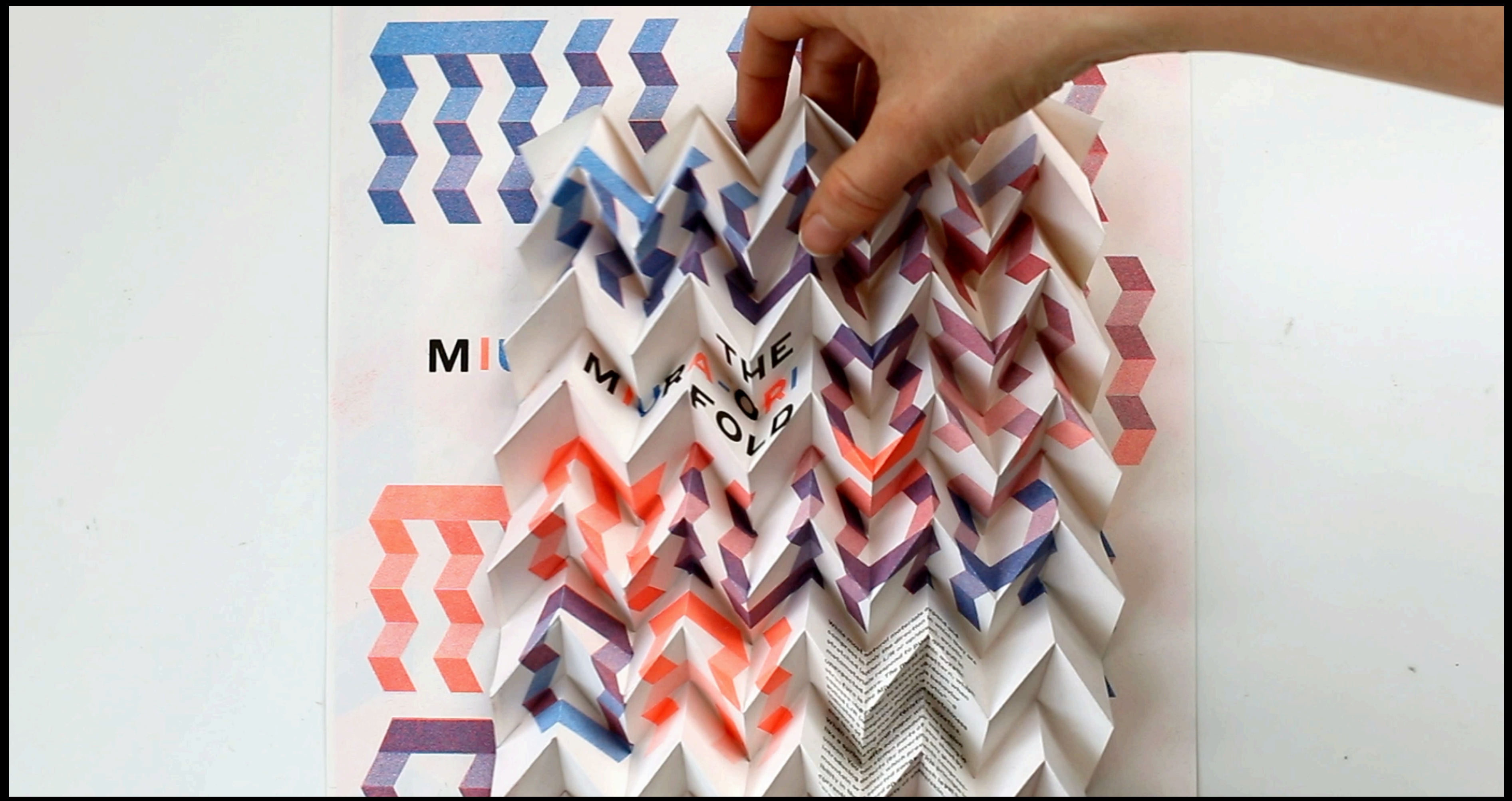


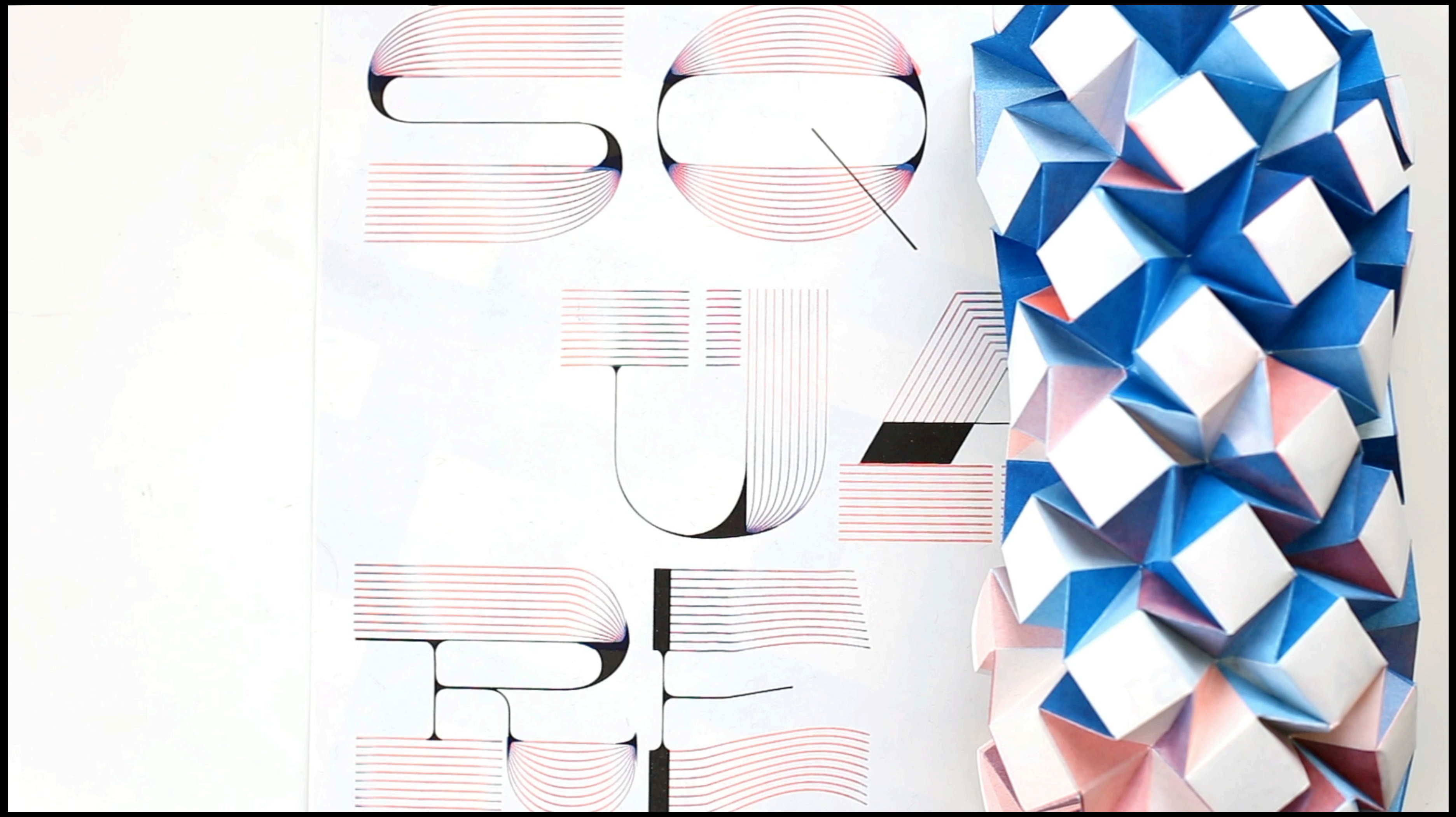
Figure 5. Hornbeam leaf showing (*a*) relatively regular corrugation, and (*b*) three-dimensional structure close to the midrib.

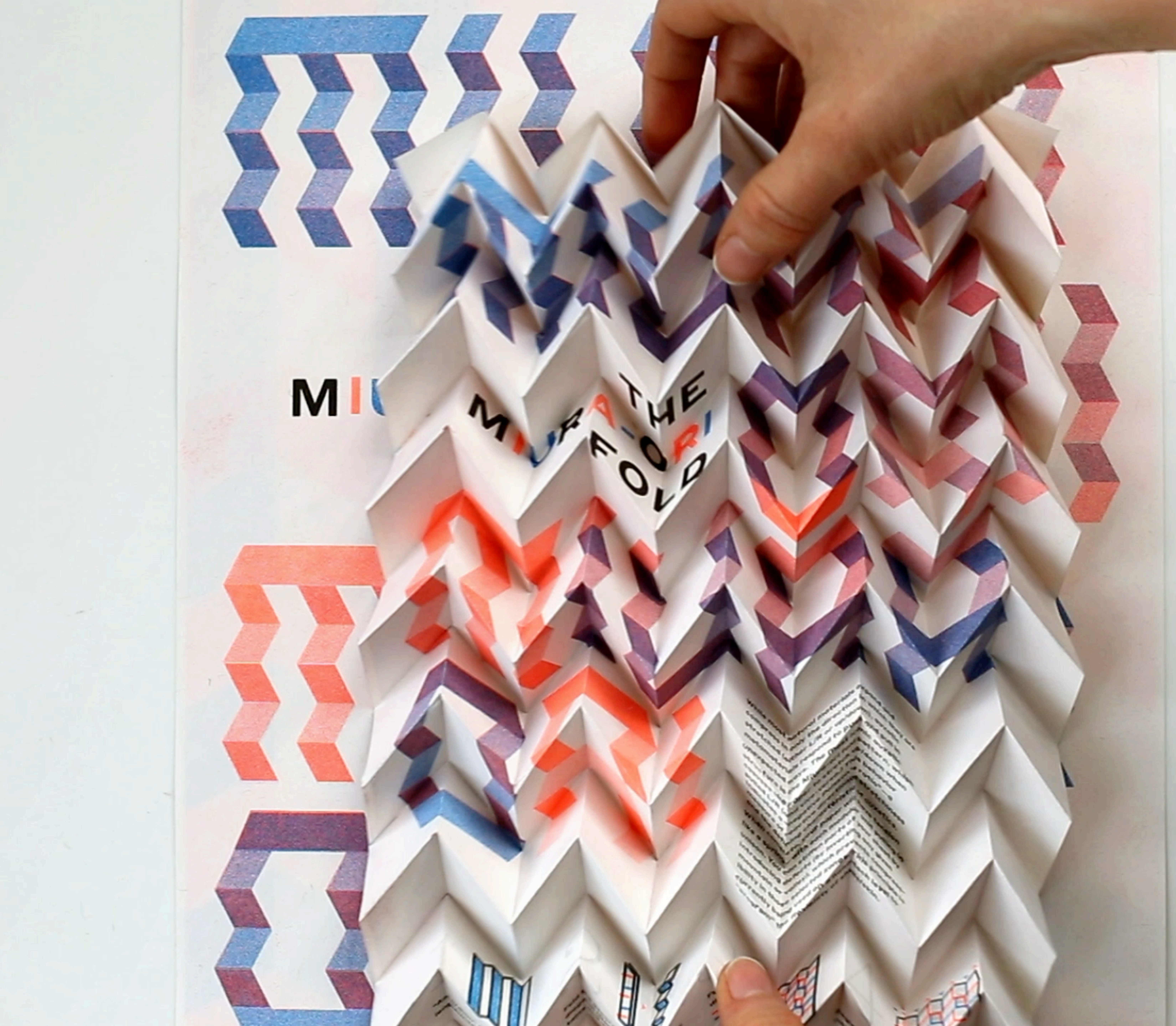


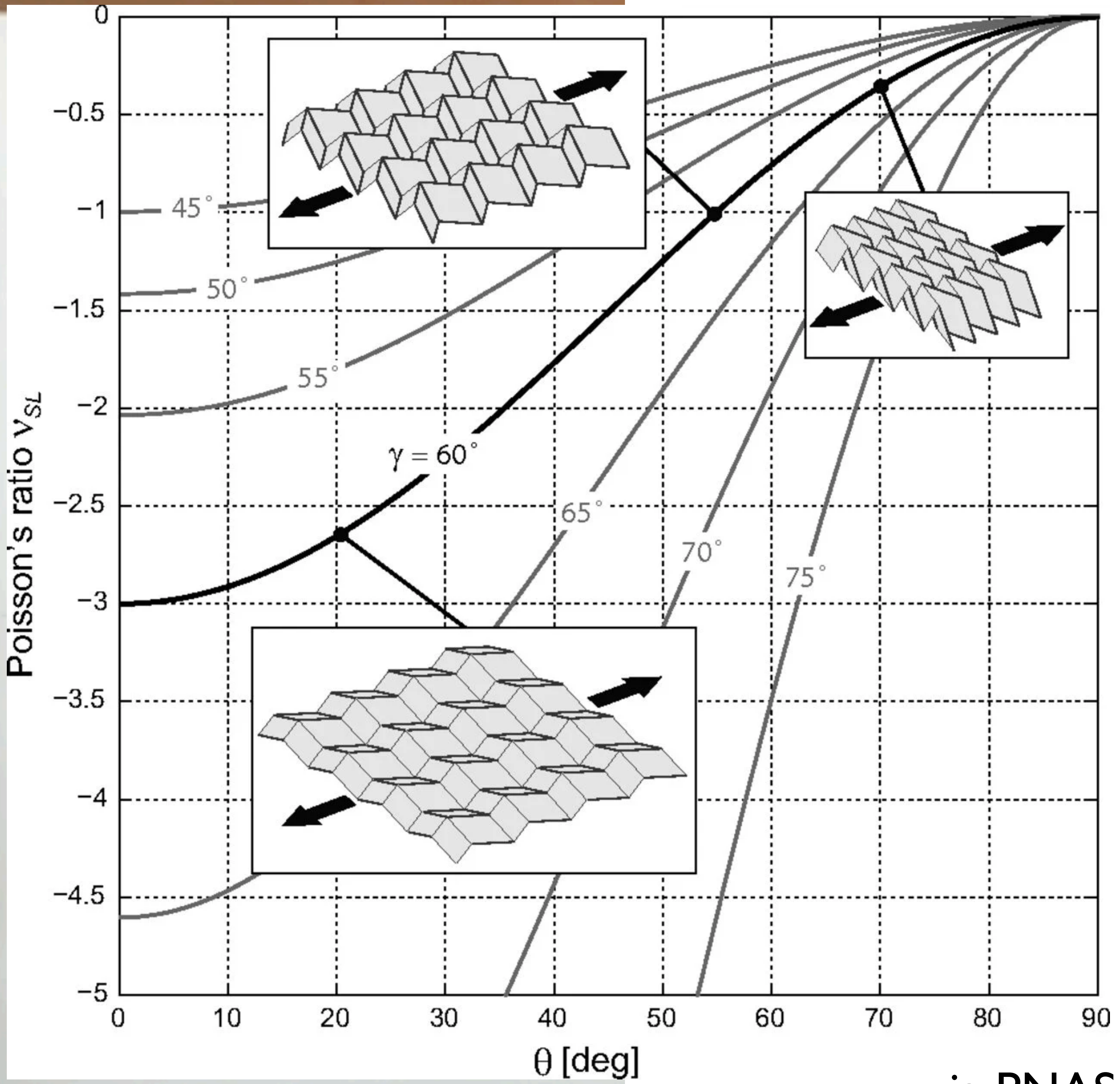
THE
MIURA-ORI
FOLD




MODIFIED
WATERBOMB
FOLD
The bissected x waterbomb crease pattern is one of the most frequently-employed base patterns in origami. This formation creates a collapsible indentation that is mechanically animated by the movemnet of adjacent miura-esque v-folds.




THE MIURA-ORI FOLD


Poisson's ratio ν_{SL}
θ [deg]
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−1
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−2
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45°
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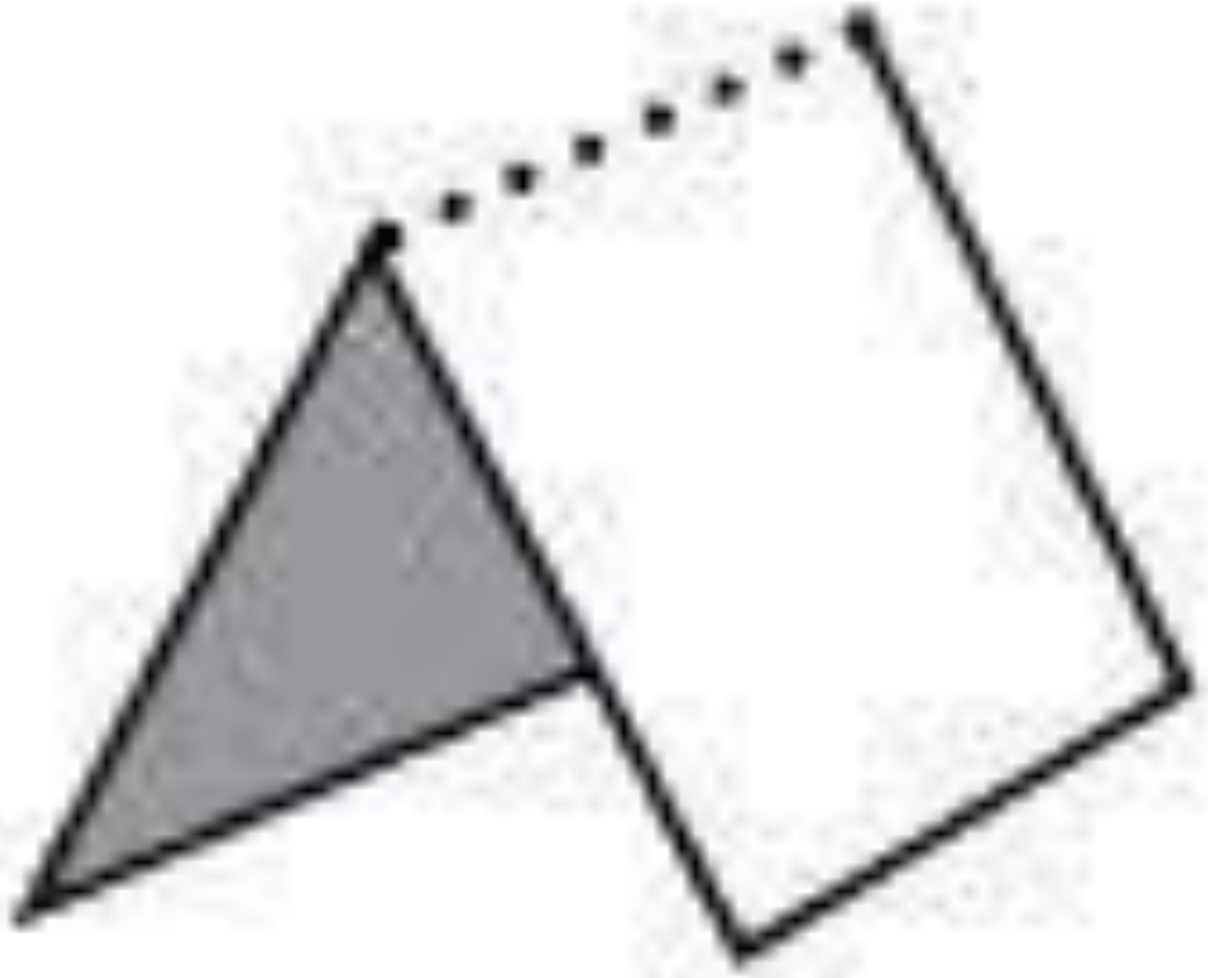
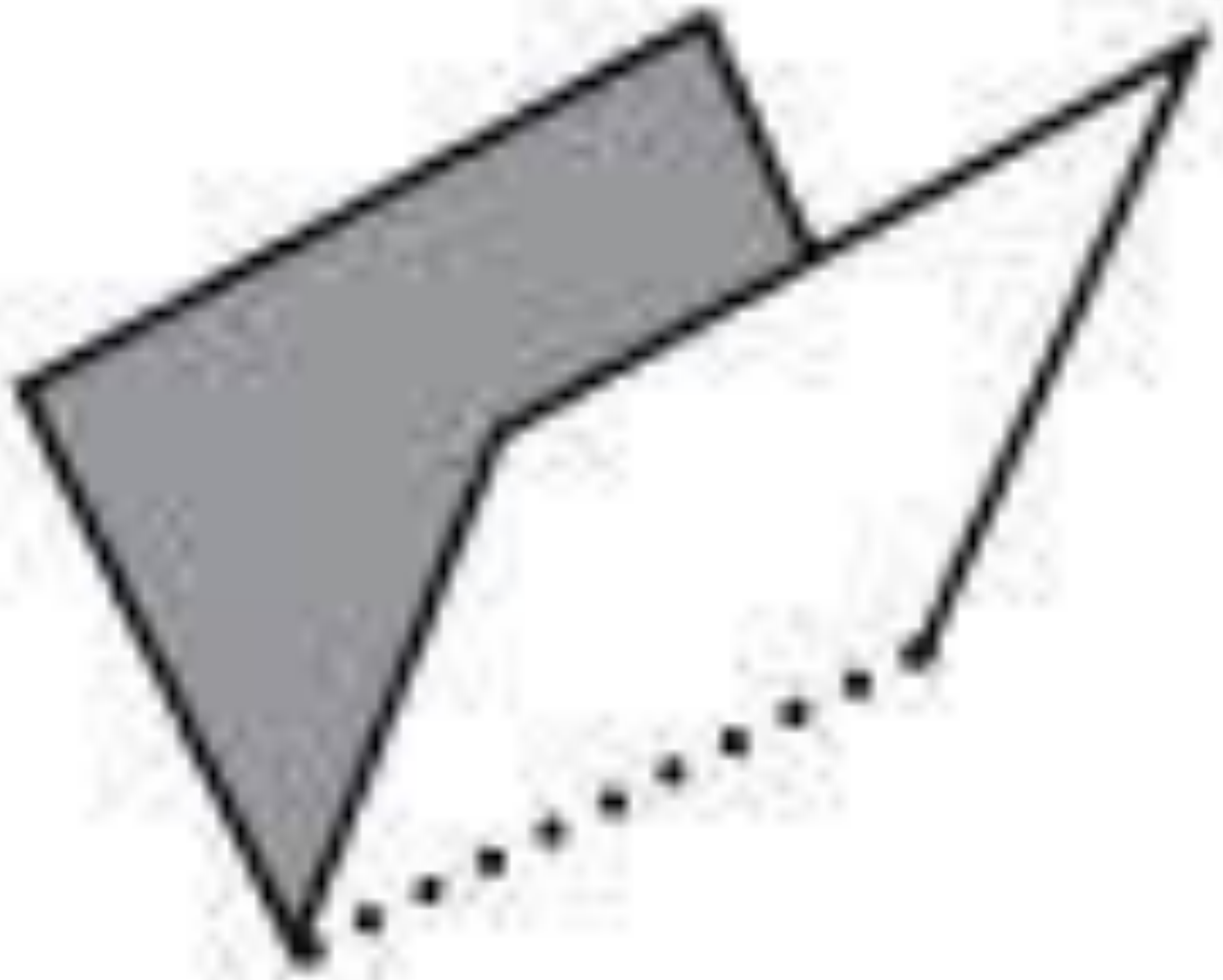
γ = 60°
65°
70°
75°

via PNAS



Mountain Fold



Valley Fold

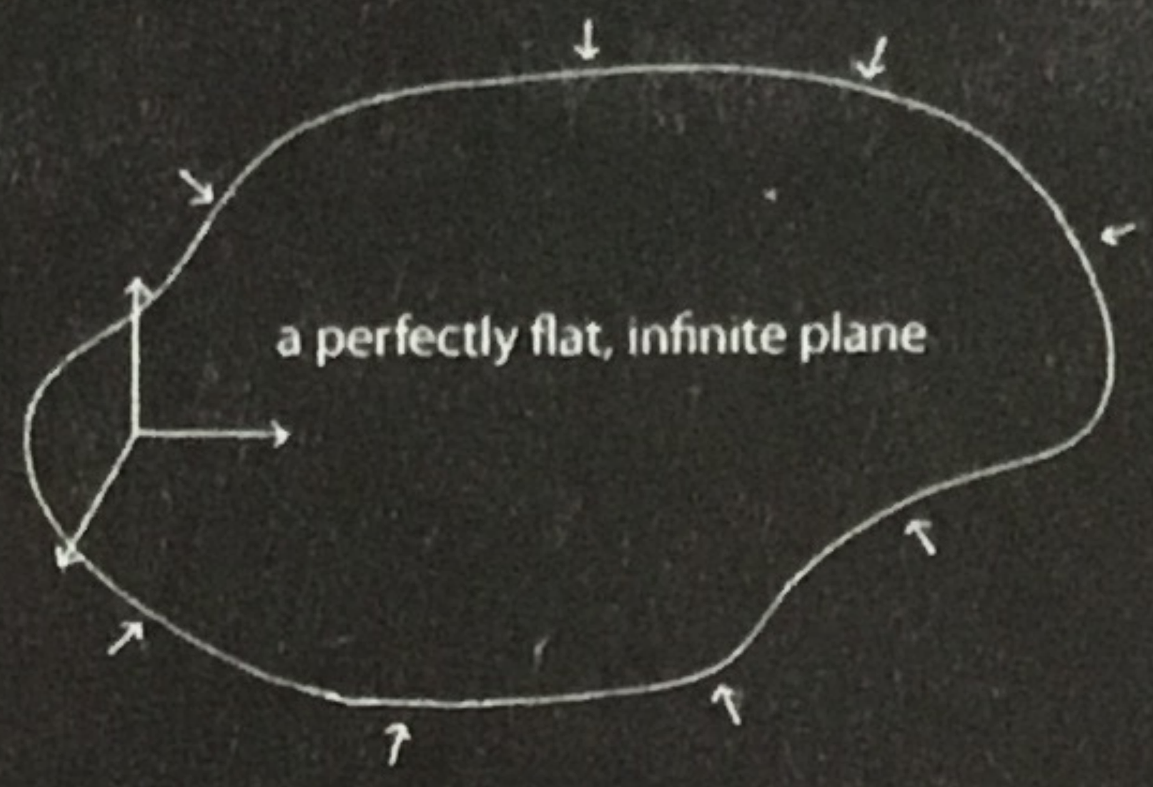


Figure 1. Conceptual drawing of the proposed problem.

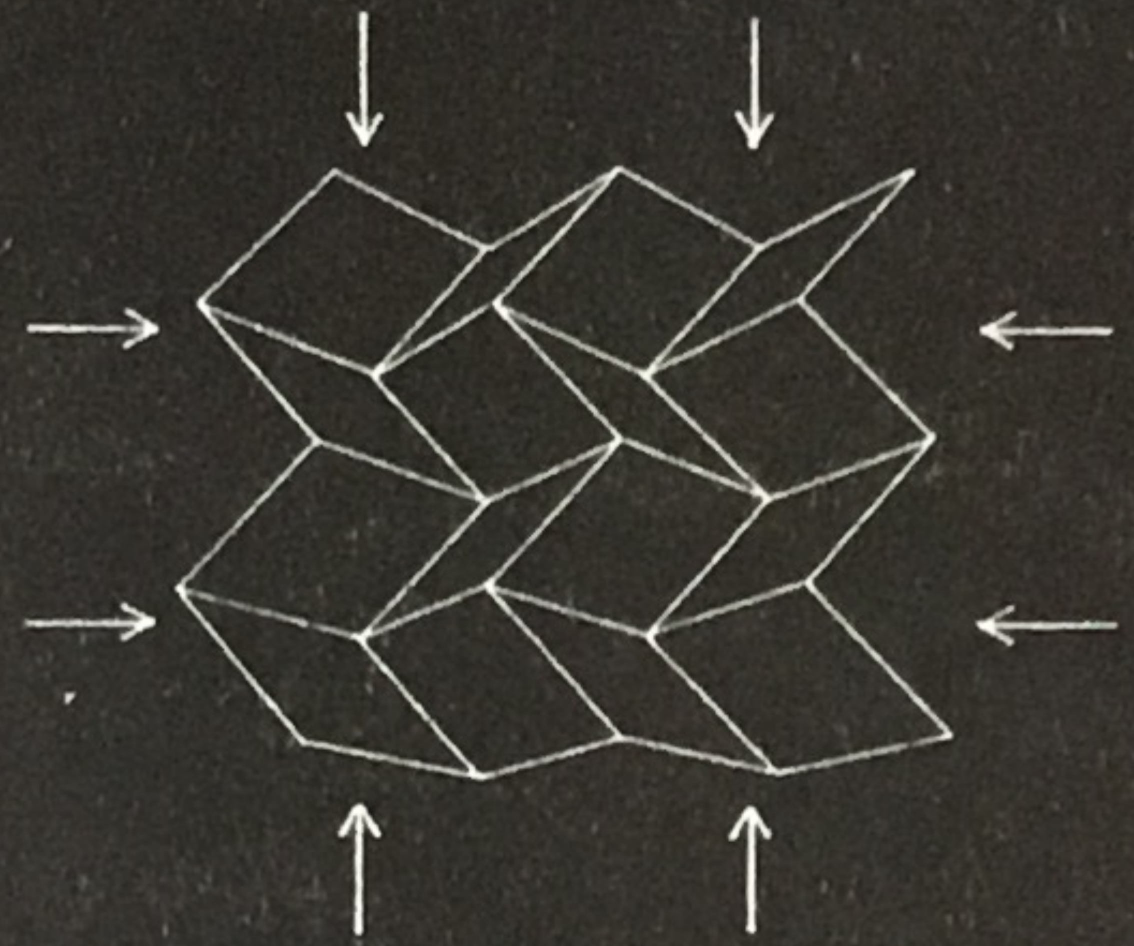


Figure 11. Surface for a thin two-dimensional elastic medium (*Miura-ori*).

Kōryō Miura

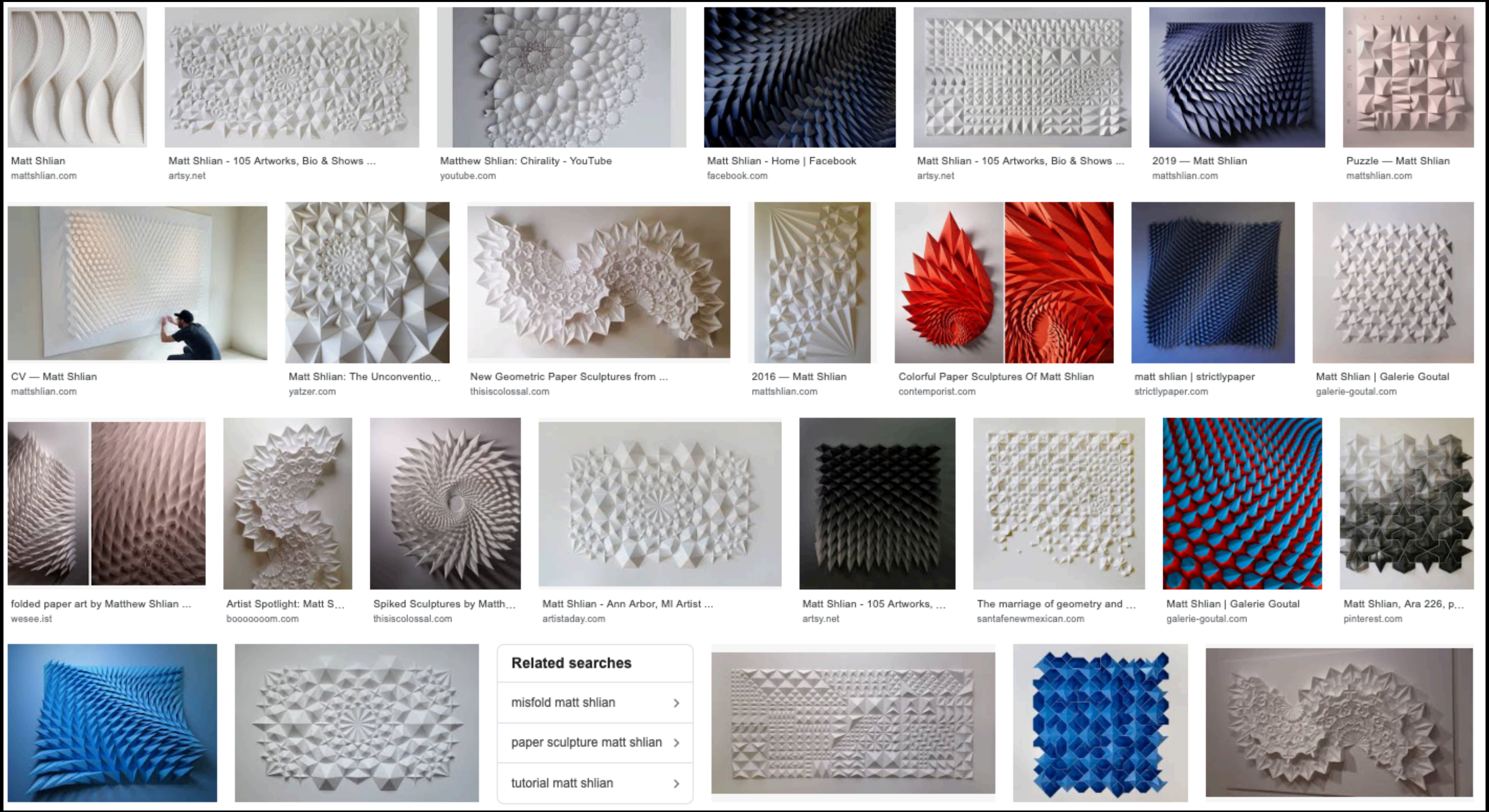
The Muiri-Ori fold being used for a solar array by Japan's Space Flyer program.

In an interesting twist, the mechanical movements produced through folding are now being called upon to solve problems in nanotech and space-craft—being reimagined again as tech.

An understanding of the basics of these paper-folding mechanics may be obtained from the contents of your recycling bin and tucked into a pocket. My favorite functional folding pattern is the Miura Ori. This pattern converts an inert sheet into a paper-thin, elastic, multi-directional paper spring. When pulled left/right, a normal piece of

"All art starts with a material, and therefore we have first to in investigate what it can do... Respect

Matt Shlian



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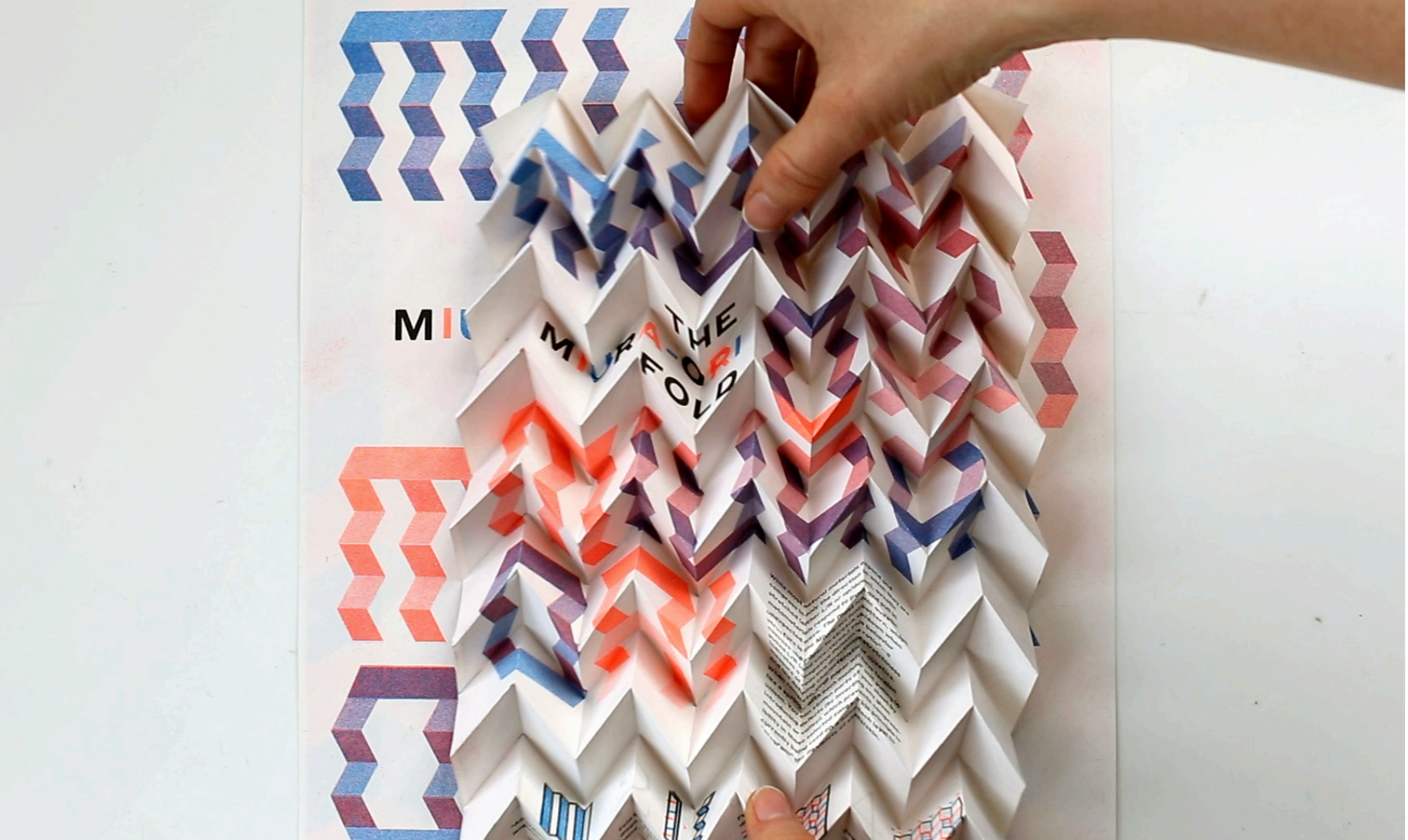
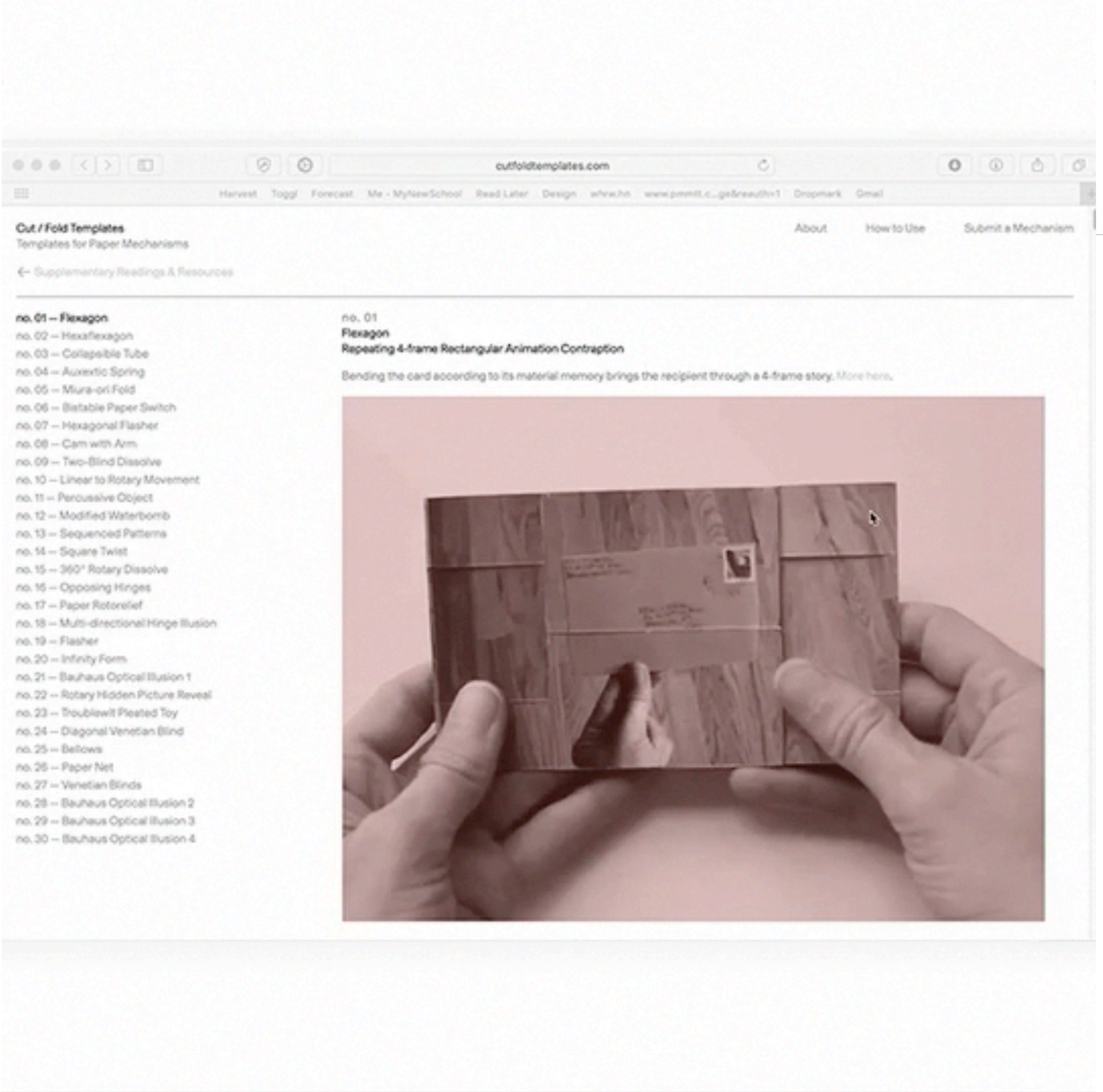

THE
MIURA-ORI
FOLD



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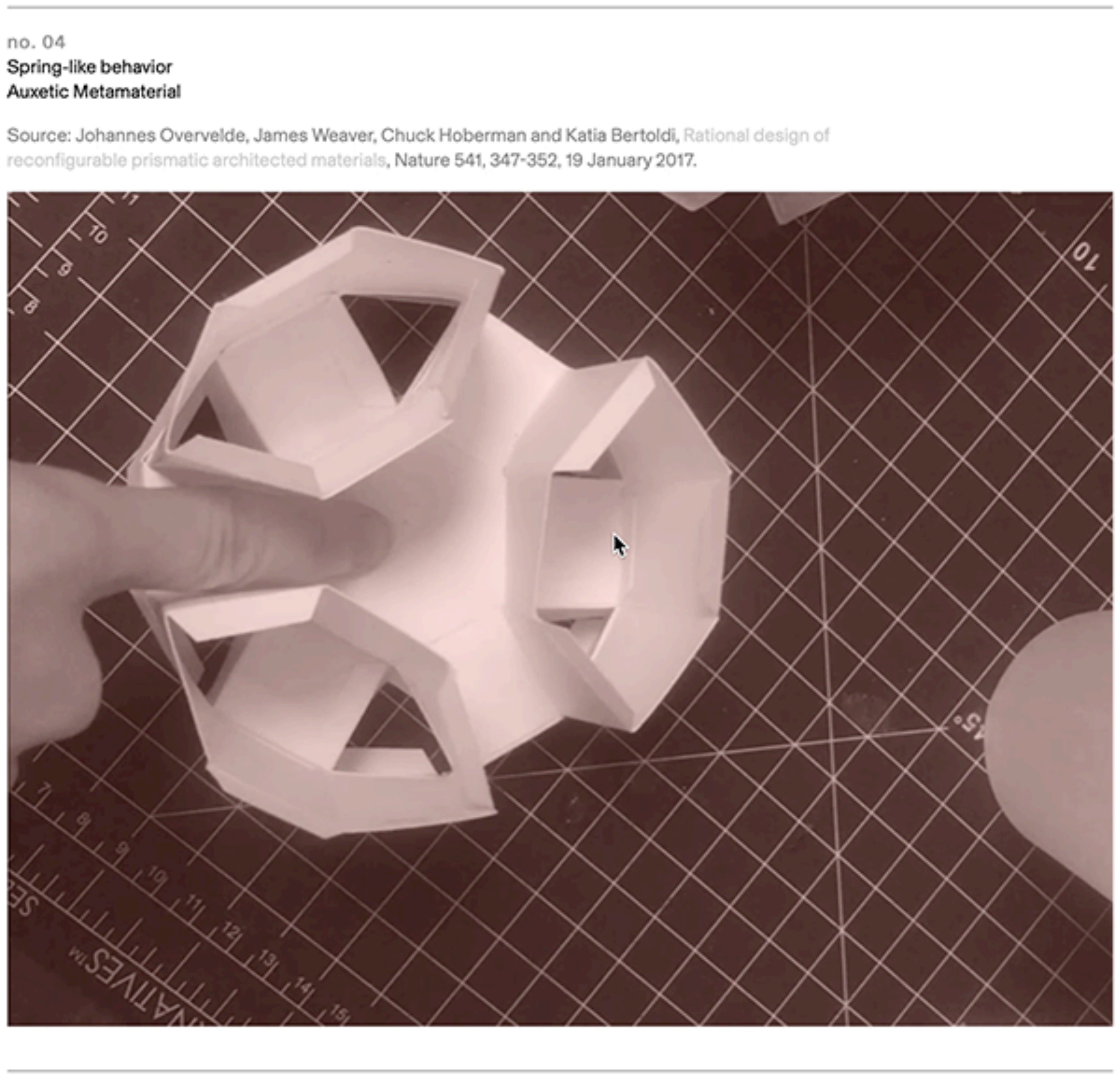

kelli@kellianderson.com