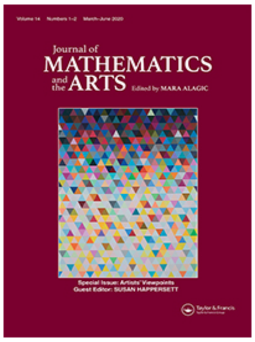

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Punica: folding Miura-ori with divots

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The transformation of a flat sheet of paper to a three-dimensional form through folding is easy and yet complex. Conceptually, folding is always in-between, bringing together two edges and the inside and outside. As a material operation, folding is always unstable. A fold stores kinetic energy, which allows the folded form to contract and unfurl. I am fascinated by folding as a tactile process of working with material – for instance, paper, or other rigid sheet materials. I am drawn to these naturally occurring folds and working on understanding how they can be analysed in order to understand the material tectonics. I use balancing, connecting, hinging, suspending, pulling and popping in my works. I often fold intuitively and tactually using small pieces of paper first, oscillating between states of disequilibrium and equilibrium.

Unfolding a folded design reveals a patterned map of creating and generating. And this map, also called a 'crease pattern', is often the result of counterintuitive deliberation and calculation based on mathematical understanding. While it is difficult to describe the folded form through the visual characteristics of the folds on this map, it is even more difficult to reverse engineer and come up with logical patterns of folds that can then be folded into desirable forms – in other words, even though one can think of or see what one wants to fold, it is still very difficult to come up with a crease pattern. I often explore mathematical understanding and computational algorithms in generating a map of folds. These final outcomes of patterns of folds are often etched and cut on very large sheets of paper using an industrial-scale laser cutter. These large sheets of paper, sometimes as wide as 5′ and as long as 10′, are then hand creased and folded in my studio.

A simple fold has many possibilities and can generate many visual results, and it can be discovered only by folding. Only through the act of folding that is grounded in material reality, one can find out what the folds want or need to become visually. To bring folds and folding together, I alternate between intuition and calculation, imagination and logic. An accidental crimp or crinkle in the small pieces of paper may reveal an internal logic to organizing and abstracting the fold. When all the folds are organized and folded in a large sheet of paper, the folding in the material may behave in a self-organized way. When this happens, I stop folding. I observe how the material self-folds and self-assembles.

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Figure 1. Punica, 2019. 22″ W by 22″ D by 26″ Hi-tec Kozo paper, stainless steel.

Punica is the Latin name for pomegranate. I named the work shown below Punica as it reminded me of the silhouette of the pomegranate flowers that I saw while growing up in Southeast China. Punica is folded based on flat-foldable Miura-ori tessellation with divots. Miura-ori tessellation, credited to Japanese astrophysicist Koryo Miura, has become well-known for its application in deployable structures, such as the solar array deployed in a 1995 mission for JAXA, the Japanese space agency (Miura, 2009). It is made of repeated parallelograms arranged in a zigzag formation and has only one type of vertices: a 4-degree of vertex. A key feature of the Miura-ori is its ability to fold and unfold rigidly with a single degree of freedom with no deformation of its parallelogram facets. Robert Lang, who wrote several books on origami and mathematics, described a method to semi-generalize the Miura-ori in order to generate any arbitrary target profile for surface with rotational symmetry without almost no mathematics involved (Lang, 2018).

In general, to fold Miura-ori into smooth curvature is materially impossible – the width of paper corrugation will be too small to fold physically. So, in order to generate folded surfaces with smooth and gentle curves, Miura-ori is altered by adding divots. Using linear algebra, I work with algorithm-based design tools such as Grasshopper and Rhino in order to study parametric changes of the folding angles and their relationships to the target smooth curved profiles. In the work shown here, an approximation of the target profile of a sine curve is generated first. And this profile curve is then arrayed and stretched into a rotational double-curved surface with both a positive Gaussian curvature value and a negative Gaussian curvature value.

When light strikes the mountain and valley creases of a folded surface, it creates dramatic effects of illuminated gradations. I use origami design to highlight the perceptual quality through the interplay of light and shadows. When a light source is placed behind an origami structure that is folded from translucent material, the light does not pass directly through the material. It diffuses through the material, much like dye diffusing through a liquid. The glaring light source on the other side of the translucent material appears fuzzy and soft when seen from the outside. And it is precisely the perceptual quality of this warm fuzziness that has drawn people of different cultures since ancient times.

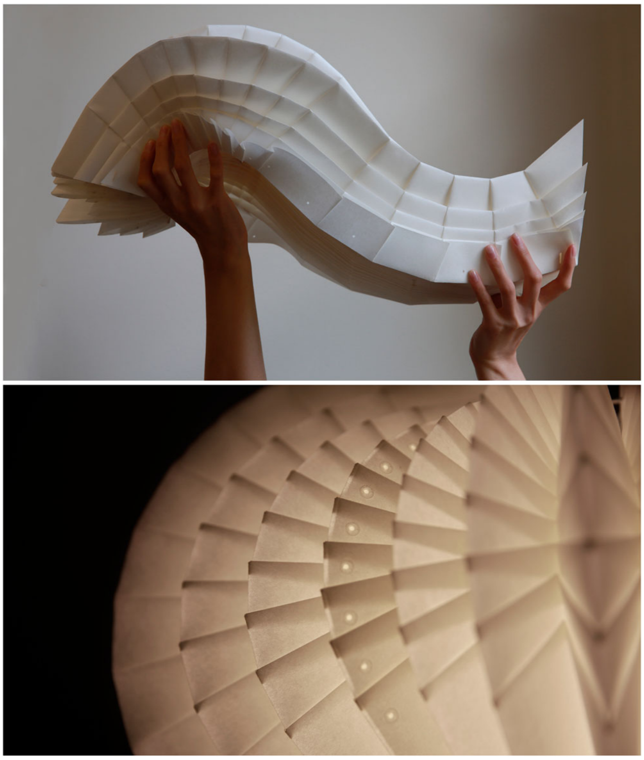

Figure 2. Punica, 2019. Top figure showing the sine wave profile when Punica is flat folded, while bottom figure showing the layered effect with the light.

In order to create more dramatic effects with Punica, the dihedral angles of the folds in Punica are carefully considered. The *dihedral angle of an origami fold* is the angle between surface normals of the two incident sectors (faces). When the dihedral angles of the folds are small, the origami mountains and valleys seem more flat. Increasing the dihedral angles of the folds to make the folds sharper will bring out more dramatic gradations changes with more contrasts in illumination. In addition, I use various material thickness to increase the contrast in Punica. Less light will pass through the surface of a material that is double or triple layered, and the illuminated surface will appear to be darker in comparison to areas where there is only a single layer of material. The layered effect in Punica is intended to highlight the movement and the rhythm.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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