Responsive Origami

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This research investigates the potential for Technical Origami as a Kinematic responsive environment that may alter its form through its folding properties, specifically in the design of vertical and overhead screens. We demonstrate the folding properties of origami tessellations and speculate on how they may be incorporated into responsive environments. Non-standard folding patterns, generated by applying the mathematics of Technical Origami, are tested to illustrate a far broader range of formal potential than modular geometrical patterns can provide. Applications are proposed that address human and environmental interaction.

In the late 1960's Ron Resch was a pioneer in the field of paper-folding for his work in establishing a conceptual framework of the inherent kinetic and structural merits certain geometric patterns held. With his 1968 Patent 'Self-Supporting Structural Unit Having a Series of Repetitious Geometrical Modules' he defined several tessellation types of what is essentially a rigid origami surface-structure. Variations of these structures have been erected, either as kinetic deployables or fixed surfaces within a larger framework. A great benefit of origami tessellations is that they are modular systems and can therefore be easily repeated for scalability or production, however that benefit bears the burden of a lack of customization or optimization geometrically.

In contrast, recent developments in computational modeling have brought rise to a new branch of paper-folding, Technical Origami, where one is able to plot out highly complex folding patterns. As technological development has turned its attention to nano-scale structures and computational strategies we are witnessing a resurgence of origami as a tool in many fields. In space exploration origami has contributed to satellite deployment techniques. In medicine, stents and other devices are being developed with origami and new efficiencies provided by Technical Origami have been adopted to an air bag folding and deployment.

Computational modeling of folding patterns for complex surfaces can also be used to develop strategies for the design of kinematic surface-structures. These surfaces have the capacity to transform from a completely flat state to a prescribed shape. The transformation becomes an opportunity to extend the surface's design potential beyond its formal attributes, into a living system that interacts with its environment.

Prototype of folding tessellation using conventional hinges. Prototype uses 'protractors' to check angular movement

Understanding the critical moments in the folding, we have identified where it is possible to remove material and done so logically, by introducing an intrinsic geometry. The same folding occurs and 95% of surfaces are planar. This means that the mechanism can easily and economically be produced. We have also found that, using materials that have bending properties, we can eliminate many of the creases in an origami tessellation.

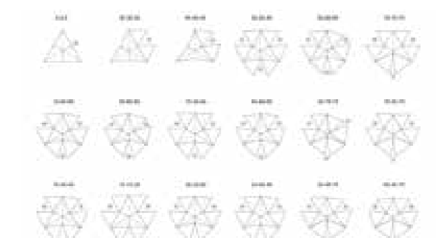
Utilizing Nitinol shape memory alloy [SMA], we are also looking to remove both mechanical hinges and servo actuators in the system, creating a solid-state actuated mechanism.

We have chosen to exploit the reverse-folding feature of the mechanism as well as the beauty of its minimal geometry by creating an ornamental component that integrates with the folding planes.

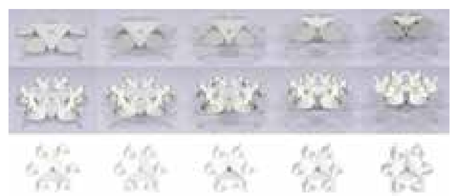
Because Technical Origami surfaces are transformable it is possible to incorporate an interaction with their environment through kinematic movement. Surfaces can be reconfigured to address different programmatic needs, as a learning environment for children, in response to environmental conditions such as wind, temperature, humidity, light, sound, and more.

There is possibly a far greater promise, however, for this system to be used at much smaller scales. Its incorporation into composite structures and micro/nano scale materials and devices may lead to new architectural possibilities.

Concept rendering of transformation reacting to occupation

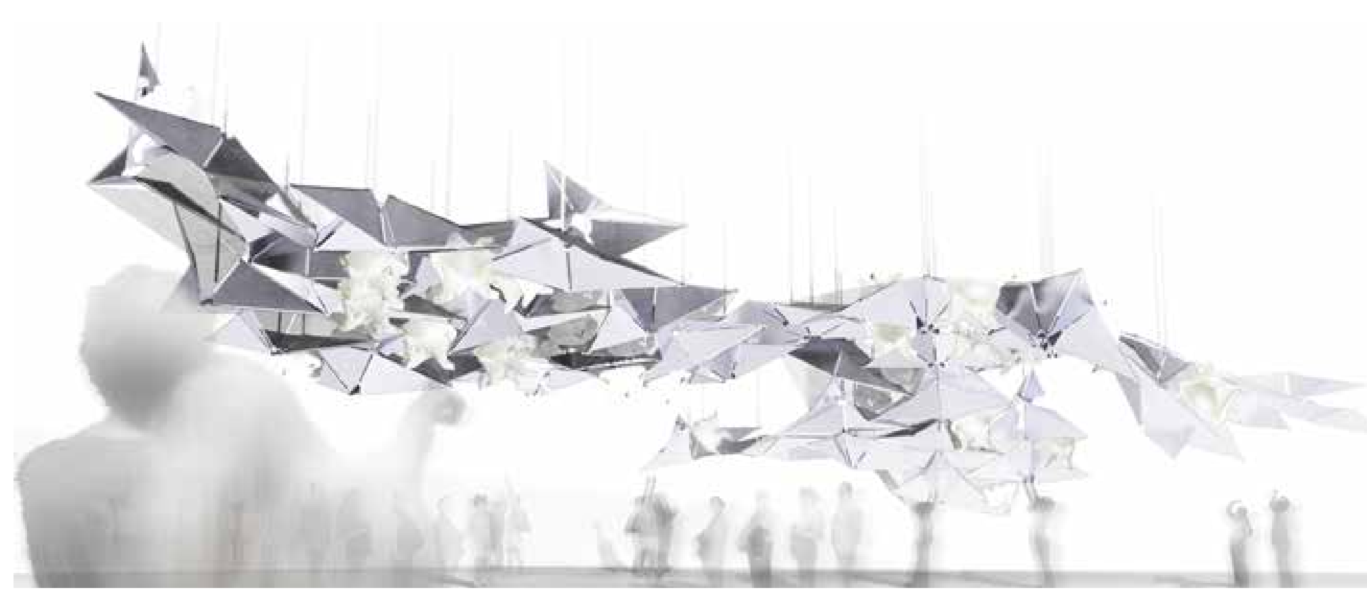


Angles were recorded with the goal of discovering all possible non-uniform variations.

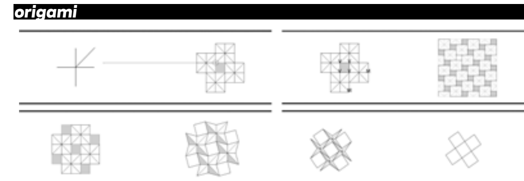


Renderings of tessellation transformations from completely open to closed. Ornamental fixtures intended to house LED's are placed on planar surfaces to create a variable display. When closed, the system is internally lit and glowing. When open, the system has directional lighting. Both lighting configurations are ties to the geometry and movement.

One of many possible configurations explored. The bottom right image is a computer simulation that shows a possible desireable fold [center] and two possible undesireabl extremes if movement is not controlled.

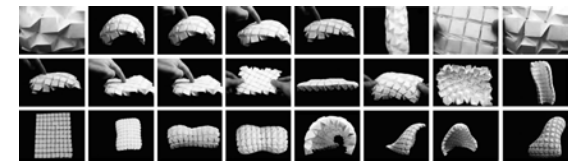


origami

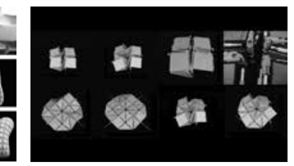


Background research included past work by author. This series of images shows development of a square tessellation and fold

tessellation studies



Many possible configurations are possible from a single, folded sheet. When folded to a certain degree the tessellation has an inherent structural property.



Prior research by author introduced a universal joint system to actuate the behavior of the surface transformation.

series two

Folding plate Jig for Shape Memory Alloy (SMA) training

Jig was required to fix Nitinol (SMA) in place

SMA can 'remember' two shapes, set to different temerature ranges

SMA can 'remember' two shapes, set to different temerature ranges

Wire was too malleable and required a rigid component

This system has an advantage of using wire to control rotation

Heating SMA. Eliminating moving parts is a major goal

Actuating SMA with 9V battery

Actuating SMA with 9V battery

Testing SMA in different configurtions and with different materials

The system we chose for further exploration used the surface material to control rotation

Some of the faces in the tessellation can be made to bend rather than hinge

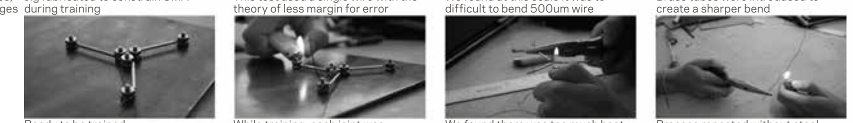
series three

Jig fabricated to constrain SMA during training

This test used a single wire with the theory of less margin for error

We found at this scale it was to difficult to bend 500um wire

Brass tubes were introduced to create a sharper bend

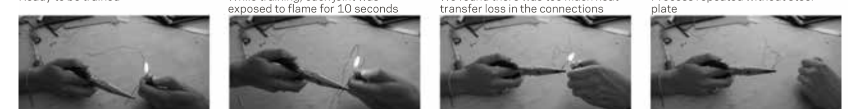


Ready to be trained

While training, each joint was exposed to flame for 10 seconds

We found there was too much heat transfer loss in the connections

Process repeated without steel plate

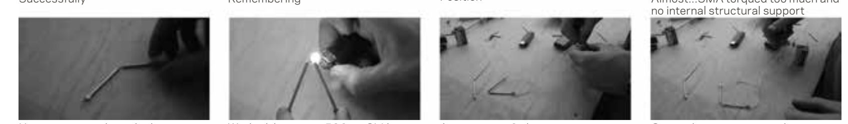


Successfully

Remembering

Position

Almost...SMA torqued too much and no internal structural support



New attempt with rigid tubing

Worked, but again 500um SMA was too rigid at scale to bend back to its original shape

Attempting a 9v battery connection was successful.

Currently we are testing this with different materials used as surfacing, attempting to combine tests