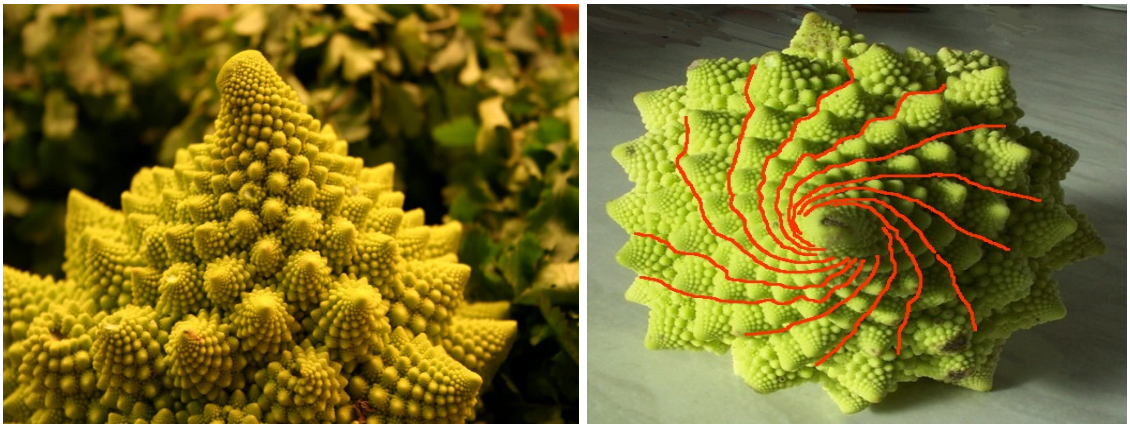
Briane Johnson - The Origami Rabbit Hole

The Easter Bunny?

For children, Easter usually means candy eggs, the easter bunny, and most importantly paper crafts. For everyone else, Easter is the celebration of the resurrection of Jesus Christ. In elementary school, I used to follow Youtube Tutorials on how to make Origami Toys for Easter and give them away to family and friends. I made origami flowers, easter baskets, and finger bunnies and as I got older made progressively more advanced modular origami projects. One day, I wondered how origami artists design their projects and if I could design some as well. Little did I know the rabbit hole that Origami would take me down…

Origami Philosophy

Origami is much more than a children's easter game, in fact it is a philosophy. The philosophy is that origami can serve a purpose to model objects and or problems in nature. Patterns and folds in nature such as the blooming of a flower, The Shell of a mollusc, and The beauty in the Romanesco Broccoli all exhibit a logarithmic spiral in some way. Origami is not just an art form in order to please the aesthetics, but has a real practical use in modeling mathematical problems, geometric shapes, and even the conversion of nature's finest designs into man-made technologies.



This is a photo of the Romanesco Broccoli. Each bud on the floret has a smaller series of buds, all arranged in the same spiral pattern with a perfect geometrical progression.

“Origami, the art of paper folding, is an emerging platform for mechanical metamaterials” (Mahadevan, 2021). Researchers in robotics, medicine, astronomy, and nanotechnologies want to duplicate nature’s folding principles, and implement it into made made technologies. For example an origami prototype of a collapsible cardiac stent was developed by a British-Japanese team from Oxford University. The collapsible cardiac stent can be inserted safely through the artery, but instead of having to be inflated by a balloon, the stent would unfold automatically by the user’s body temperature and would widen the artery to the right size. Using basic origami folding techniques, this type of stent would be more flexible and therefore better match the elasticity of a blood vessel. A simple geometric model can help so many in need of cardiac surgery.

Additionally, Origami geometric principles have been used in aerospace engineering. The Miura-Ori Fold, created by Japanese astrophysicist Koryo Miura is a paper folding method

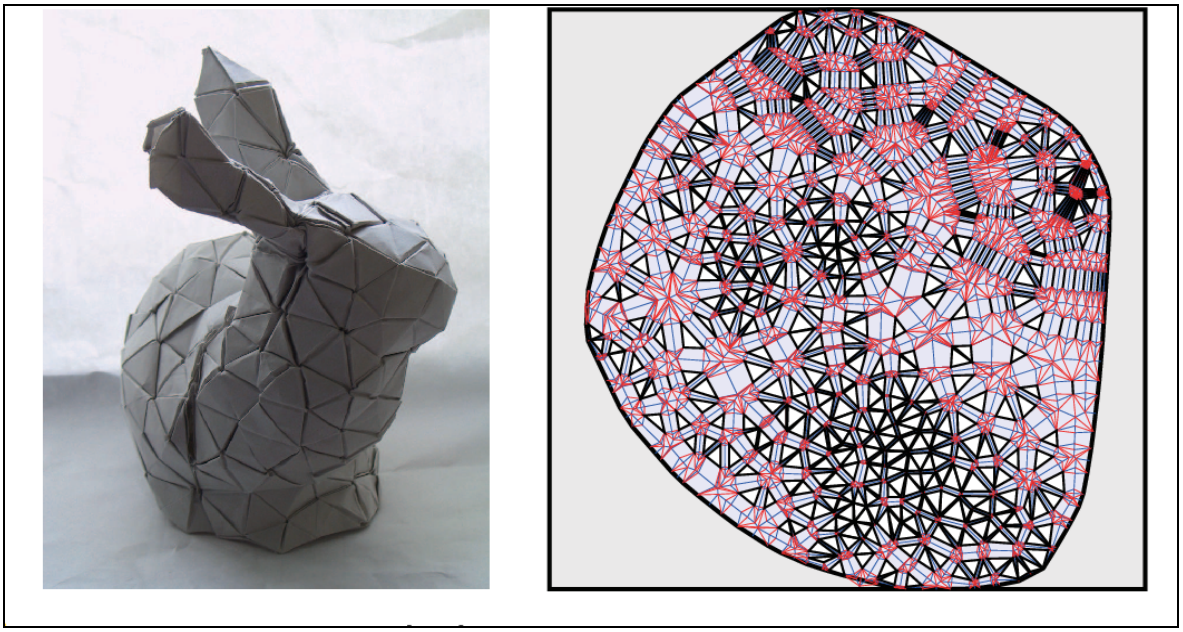
which folds a flat sheet of paper into a smaller area. The fold creates a series of “zig zags” across the sheet, where the crease patterns in the fold create a tessellation of the surface using parallelograms. This type of fold can easily be compressed into a compact state, where the strength of the structure folded and width are inversely proportional. On an airplane, engineers have employed the use of this fold in order to build the fuselage or “body” of a plane. The structure is called a Miura-ori sandwich (Not very appetizing), Where the folded plate is placed between two unfolded plates in order to create a strong structure. Utilizing the “Miura-ori sandwich plates” can help to create a light, but strong design and save space in the plane. Just one segment of these plates that weighs 10 grams can withhold the weight of one ton, and reduce overall weight of the place, cutting down on fuel consumption.

What is the Point?!

A common question that Origami artists get asked is what is the point? Why can’t you cut the piece of paper or use glue? The goal of many in the field of computational geometry is to find the mathematical attestation of the “Origami Code”. Basically, the Origami Code would be a methodology for folding any Three dimensional shape from a single sheet of paper. As seen above, principles in origami folding have been used to better technologies in order to help people. Being able to create any three dimensional shape from a single three dimensional sheet of material can help to save resources, assembly time, money, and help to create an overall sleek design. The Origami Code could be the future not only of computational geometry, but mathematics itself!

Origami Treemaker

Back to my original question that sent me down this rabbit hole, “how do origami artists create these designs?” Origami Treemaker is one way. A pioneer in the field of Origami artistry and theory is The American physicist Robert J. Lang, who created the computer software “treemaker” where users can create 2D crease patterns, which can be used to create 3D origami shapes. Professors in computational geometry such as Erik Demaine (Massachusetts Institute of Technology) and Tomohiro Tachi (University of Tokyo) utilize Treemaker, and programs similar to it in order to prove one day that any shape is foldable from a single sheet of paper. Creating an origami crease pattern is not as simple as using the computer software, but takes some more knowledge about the process. One part of this “hare-y” piece of mathematics is the idea of circle decomposition, where you draw circles in order to indicate the amount of paper devoted to each flap of the crease design. Where the circles touch, or overlap is called an “active path” and active paths will always be creased in the pattern.

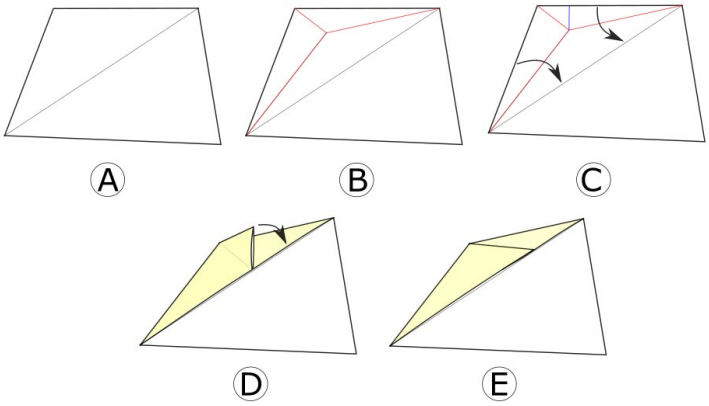


This is a photo of the Stanford bunny (origami model), alongside the crease pattern used to create it. The Stanford bunny is a 3D test model developed by Greg Turk and Marc Levoy. This model consists of some 64,451 triangles!

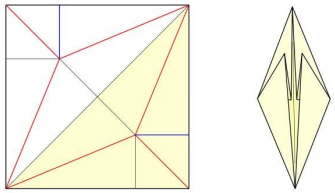
Rabbit Ear Theorem

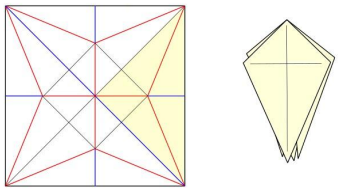
The Rabbit Ear Theorem is another principle used in designing basic origami artwork. In this appropriately named theorem, we learn how to make three lines, folds, or points (ABC) that form a triangle coincide. This is a common way in origami to make the ear of an animal.

"Given a triangle ABC, let O be the incenter so that AO, BO, CO are angle bisectors. Let XO be a perpendicular drawn from O to any one of the three sides of the triangle. Then O with the crease Lines AO, BO, CO, and XO is a flat-foldable vertex." (Hull, 2021). This theorem is illustrated below



Additionally, you can mirror the pattern above across the same sheet of paper to get a common origami base (as seen below)





Origami can be used to model geometric patterns, but as itself can be considered a complex mathematical topic. When I see origami, I can think of it as the translator of the natural world into mathematical concepts and models that people can understand and mimic. Origami is both the recreation of small children and professors of computational geometry. Many schools in K-12 use hypothetical situations in order to teach mathematics, and often fail to apply it to the child's

own lives. Origami can even be a way to teach mathematics, by creating models for the students. As a fun activity next holiday, instead of gifting my family already made origami bunny figurines, I can gift them the crease pattern and have them race to create the shape.

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