Questions Received from Online Audience – Answers Provided by the Lecturer

Is there a connection between these algorithms and Voronoi tessellation algorithms?

Very much so. In a work with Alex Bateman ("Every spiderweb has a simple flat twist tessellation"), we showed that one can construct tessellations consisting of simple flat twists from a planar graph and its reciprocal diagram, and since a Delaunay triangulation of a set of points is the reciprocal diagram of a Voronoi graph of that same set, this algorithm works for any Voronoi diagram. An example making use of this concept, which is one of my favorite pieces, is at https://langorigami.com/artwork/37-hyperbolic-limit-opus-600/. One can also create one's own Voronoi-based origami tessellations using functions in my *Mathematica* package for origami design, *Tessellatica*, which you can find here: https://langorigami.com/article/tessellatica.

China had paper folding arts for a long time. Are there any documentation on this?

There's very limited documentation of ancient decorative paper-folding in China, even though the Chinese invented paper several centuries before paper came to Japan. Xiaoxian Huang has made a study of the history of Chinese paper-folding, and while there are definitely examples of people folding paper in antiquity in China, the oldest record of what we might call "origami-like" folding that we know of is an early 20th-century book by Guo Shaolie. There was, of course, also significant cultural interchange between Japan and parts of China around that time, which further muddles the picture of what might have been independently developed. Nowadays, origami is pursued worldwide, and there are several world-class origami artists in China, as well as a great deal of cutting-edge origami/engineering research.

Fascinating talk ! So inspiring! Do you see the potential of pairing Origami with Kirigami? Would you see this as an opportunity?

In the art world, "origami" (folding with few or no cuts) and "kirigami" (folding with lots of cuts) are rather distinct genres these days, although in older Japanese origami works, there was more cutting used than is common nowadays. In the engineering applications of origami, though, using cuts—and calling it "kirigami"—is not uncommon, and people don't make much of a distinction between origami and kirigami other than what they choose to name it; the attitude is "use folding or cutting or both as needed, whichever gives the best technical solution."

Are there materials that could mimic the unfolding of plant tissues like leaves and petals, which have the properties of both unfolding and expansion of the material contained within the fold?

There's not much. There are definitely stretchy materials that can expand, but stretchy materials don't take a crease very well, and even those don't have the large change in scale that we see in plants going from bud to full-scale petal or leaf. There are examples of plant structures that start folded and then unfold as well as expand, notably beech leaves, which use a fold pattern very similar to the famous Miura-ori pattern of space solar fame. It would be a very interesting materials science project to develop a material that is both foldable and (selectively) swellable to mimic such structures.

Are there specific principles that can be followed for models intended to move after achieving their final shape? For example, the flapping bird - it's one thing to get it into shape, but certain tensile, compressive and shear load paths (more) are present in the completed form that give it the ability to do a targeted movement that's not just folding and unfolding of the pattern itself. What ideas underpin that?

There is a large body of study devoted to origami mechanisms that move! On the art side, this type of model is referred to as "Action Origami" (and there is a book of such figures by that name); on the engineering side, it can be found in the fields of mechanics, where it is known as the topic of "rigid foldability" and also stress-strain analysis within folded mechanisms. Origami mechanisms can have smooth motion or multistable behavior with rich and complex energy landscapes between minima, making it a rich field for investigation. It's an area of active research by many engineers, primarily in the area of mechanics, but also in the field of computational geometry (part of computer science).

Hello Dr. Lang. Have you ever had experience doing research with origami applications in soft robotics, and do you have any thoughts about the recent expansions and developments in that field?

I've not done any work combining origami with soft robotics yet—although interestingly, as a result of this talk, I've started some preliminary discussions with researchers where we've seen some areas of potential overlap. But it's too early to say anything definite.

Thanks for your questions, everyone, and thanks for attending my talk! (And happy folding!)'