Physicists are decoding math-y secrets of knitting to make bespoke materials

Enlarge / Introducing topological defects into knitted patterns can shape the (a) out-of-plane elasticity of a stuffed rabbit (left), and (b) the in-plane deformations of knitted textiles (right).
Elisabetta Matsumoto

reader comments

11 with 11 posters participating

Share this story

Knitted fabrics like a scarf or socks are highly elastic, capable of stretching as much as twice their length, but individual strands of yarn hardly stretch at all. It's the way those strands form an interlocking network of stitches that give knitted fabrics their stretchiness. Physicists are trying to unlock the knitting "code"—the underlying mathematical rules that govern how different stitch combinations give rise to different properties like stretchiness—in hopes of creating new "tunable" materials whose properties can be tailored for specific purposes.

"Knitting is this incredibly complex way of converting one-dimensional yarn into complex fabric," said Elisabetta Matsumoto, a physicist at the Georgia Institute of Technology. "So basically this is a type of coding." Figuring out how different stitch types determine shape and mechanical strength could help create designer materials for future technologies—everything from better materials for the

aerospace industry to stretchable materials to replace torn ligaments. The models her team is developing may also be useful in improving the realistic animation of clothing and hair in video game graphics. Matsumoto described her research during the American Physical Society's 2019 March meeting taking place this week in Boston.

Knitted fabrics can technically be considered a type of metamaterial (engineered materials that get their properties not from the base materials but from their designed structures), according to Matsumoto, who points to the medieval embroidery technique known as "smocking" as an early example. From a physics standpoint, smocking uses knots to essentially convert local bending energy into bulk stretching energy.

> *"There's this huge wealth of knowledge in the knitting community that hasn't been translated into a quantitative model yet."*

The elasticity (aka stretchiness) of knitted fabrics is an emergent property: the whole is more than the sum of its parts. How those components (strands of yarn) are arranged at an intermediate scale (the structure) determines the macro scale properties of the resulting fabric. It's analogous to a lump of gold, which is made up of millions of atoms at the microscale and has macro scale properties like hardness and its golden hue. But the individual atoms themselves do not possess those properties, just like the individual strands of yarn don't stretch the way a knitted scarf does.

An avid knitter since childhood, Matsumoto started pondering the underlying mathematics when she went into science and developed a new appreciation for all the math and materials physics behind her hobby. "There's this huge wealth of knowledge in the knitting community that hasn't been translated into a quantitative model yet," she said. "We're trying to take that knowledge and bring it into the physics

world, where we can study these as materials and look at elasticity and other emergent properties.”

In essence, knitted fabrics are composed of an interlocking series of slip knots composed of a single thread hooking back and forth on itself. (Woven fabrics, in contrast, are composed of multiple threads crossing each other.) To make a knitted stitch, you pull the slip knot through the front of the fabric; to make a purl stitch, you pull it through the back of the fabric. Experienced knitters know how to combine those stitches in many different ways, playing with the topology and creating intricate new shapes—including elaborate 3D shapes, like a stuffed rabbit. And changing the topology will also change the emergent properties (like elasticity).

Enlarge / (a) Knitting is a periodic structure of slip knots. (b) Textiles with intricate patterns are knit by combining slipknots in specific combinations.

“There are hundreds of books with thousands of patterns of stitches, with seemingly unbounded complexity,” said Matsumoto. “And every type of stitch has a different elasticity. By picking a stitch, you are not only choosing the geometry but the elastic properties, and that means you can build in the right mechanical properties for anything from aerospace engineering to tissue scaffolding materials.”

Matsumoto isn’t the only physicist intrigued by the remarkable complexity of this ancient craft. Just last year, a team of

French physicists developed a rudimentary mathematical model to describe the deformation of a common type of knit. Their work was inspired when co-author Frédéric Lechenault watched his pregnant wife knitting baby booties and blankets, and he noted how the items would return to their original shape even after being stretched. With a few colleagues, he was able to boil the mechanics down to a few simple equations, adaptable to different stitch patterns.

It all comes down to three factors: the “bendiness” of the yarn, the length of the yarn, and how many crossing points are in each stitch. The stretchiness of knitted fabric results from the loops created as the yarn in one row of stitches weaves through the rows above and below because pulling on, or bending, the fabric creates energy, which in turn distorts the loops. Exactly how much it can stretch is limited by how many times the yarn crosses with neighboring stitches, as well as the yarn’s length. They tested their model by stretching knitted fishing line (which doesn’t generate as much friction as yarn) to see if its behavior matched the model’s predictions—and it did.

Naturally, more research is needed to realize the full potential of knitting in so-called “additive manufacturing” (i.e., creating an object by building it one layer at a time). But there may soon come a day when knitting’s secrets are fully revealed, enabling scientists to program in topological defects, much like they introduce defects into crystalline structures to get desirable material properties. They’ll be able to customize knitted materials with very specific shapes and properties, the same way skilled knitters transform strands of yarn into intricate three-dimensional shapes. All they need to do is crack the code.

https://arstechnica.com/?p=1468163