

PRESS RELEASE

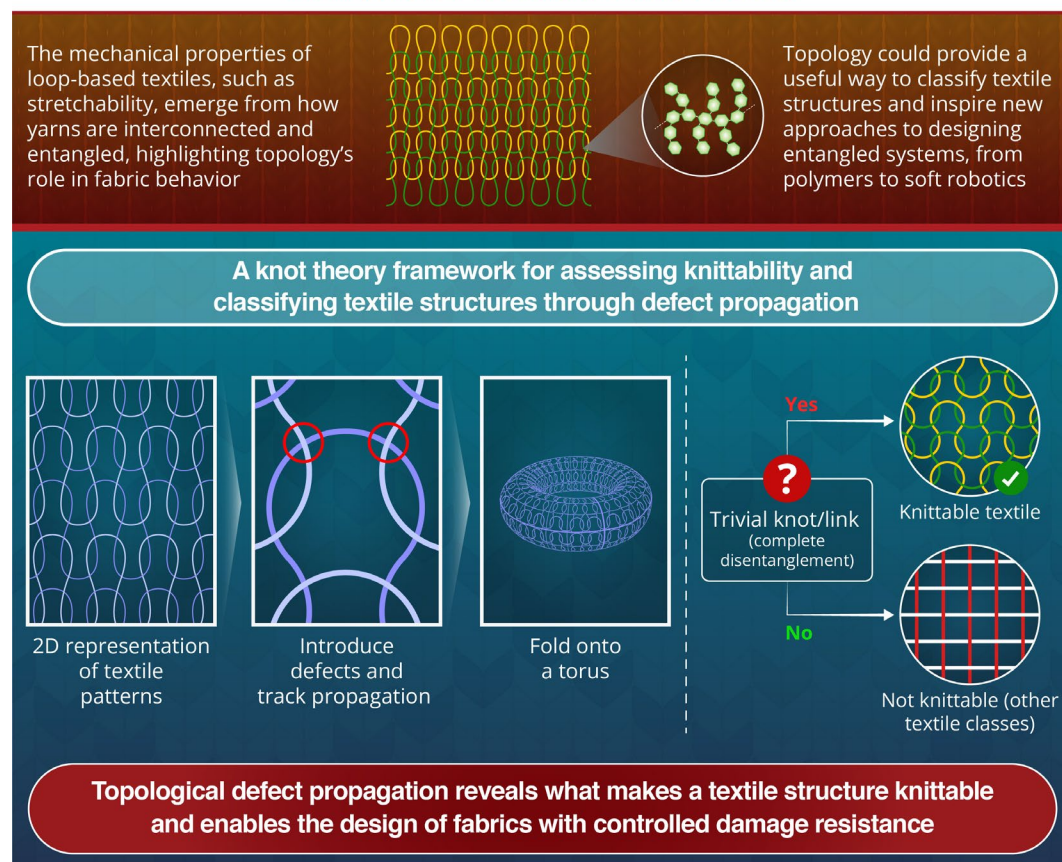
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Understanding Textile Structures by Studying Defect Propagation

Researchers classify periodic textile structures by mathematically tracking how defects propagate through interconnected yarn networks

Textile properties often depend as much on yarn entanglement as on the material itself, with these underlying patterns influencing mechanical behavior. Researchers have developed a mathematical framework that classifies periodic textile structures and identifies the features that define knittable textiles through the propagation of defects. The findings could help design fabrics with tailored mechanical properties and provide insights into how the underlying structure affects the properties of other entangled materials, from polymers to soft robotics.

Topology-Based Classification of Knittable Textile Structures



Fabrics are made by repeatedly intertwining yarns into characteristic patterns. Many of their properties, such as stretchiness, arise not only from the material itself but also from how the yarns are arranged and entangled. Such properties illustrate how topology—the underlying patterns of connectivity and entanglement within a structure—can shape a material's overall behavior. Understanding these relationships could help researchers design materials with tailored properties through the design of their topology.

A research team led by Dr. Daisuke S. Shimamoto, a Senior Researcher from the Research Organization of Science and Technology, Ritsumeikan University, Japan, along with Dr. Keiko Shimamoto, an independent researcher from Tokyo, Japan, Dr. Sonia Mahmoudi from Tohoku University, and Dr. Samuel Poincloux from Aoyama Gakuin University, have developed a mathematical framework based on knot theory for characterizing knittability and classifying periodic textile structures based on how defects spread through them. Their findings were published in [*Physical Review X*](#) on July 14, 2026.

The researchers found that defects appear as disruptions in repeating textile patterns and spread through structures in distinct ways depending on their topology. By analyzing these propagation patterns, the framework can determine whether a textile structure is knittable and classify different types of periodic textiles. According to Dr. Shimamoto, understanding defect propagation could guide the design of novel fabrics with tailored mechanical properties.

“These defects appear as disruptions in repeating stitch patterns and spread through the structure in distinct ways. This process of propagation of defects described in our framework could guide the design of novel knitted materials with unusual mechanical properties and improve our understanding of other systems shaped by topology,” says Dr. Shimamoto.

The researchers represented knitted and crocheted fabrics as two-dimensional textile diagrams composed of one-dimensional curves, modeling them as repeating, grid-like patterns of interconnected loops. They then introduced defects into the repeating pattern and analyzed how they propagated through neighboring regions of the textile without the yarn being damaged. To determine whether a textile was knittable, they folded the resulting defect-containing pattern onto a doughnut-shaped surface called a torus and examined whether the resulting knot or link could ultimately be disentangled into simple loops without crossings. A textile was considered knittable if defect propagation transformed the structure into a topologically trivial knot or link.

Using this framework, the researchers were able to identify loop-based structures, such as knitting and crochet, from other textile classes. They also found that by controlling how defects spread through a textile, they could influence how damage develops within the structure, providing a new route to fabrics with tunable mechanical properties such as damage resistance.

Based on these principles, the researchers also designed textiles that suppress defect propagation and therefore undergo limited damage. Similarly, they designed textiles that

amplify damage propagation and unravel easily, demonstrating the advantage of mathematically understanding the topology.

Beyond textiles, the framework offers a new way to explore how topology influences the behavior and mechanical properties of entangled systems, including polymers, biological tissues, and soft robotic materials.

“Our study connects traditional textile crafts with modern mathematics and physics. It provides a systematic way to explore and design textile structures based on topology. It could help develop more durable fabrics without changing the material itself, simply by modifying the entanglement pattern. Since entanglements appear in many systems beyond textiles, including polymers, biological tissues, and soft robotics, it may also inspire new approaches to designing and understanding complex materials,” says Dr. Shimamoto.

Reference

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About senior researcher Daisuke S. Shimamoto from Ritsumeikan University, Japan

Dr. Daisuke S. Shimamoto is a Senior Researcher at the Research Organization of Science and Technology, Ritsumeikan University, Japan. His research explores the physical properties of everyday materials and systems using simple mathematical models, combining theoretical, numerical, and experimental approaches. He studies systems where small structural changes can strongly influence mechanical or dynamical behavior, with interests spanning jammed packings, periodic tangles, and phase-separating mixtures. Dr. Shimamoto’s recent work also explores links between physics and challenges in biology, planetary science, and engineering. He has received multiple awards, including the 2025 Student Presentation Award from the Physical Society of Japan.

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