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PrimeView
Origami engineering

An origami is a 2D manifold, defined by a set of creases where the folding occurs and folding angles to determine folding amount. Creases are classified as mountain (*M*) when folded up and valley (*V*) when folded down. *M*/*V* assignments are relative to the viewing angle but always opposite, forming the blueprint for origami assemblies.

Experimentation

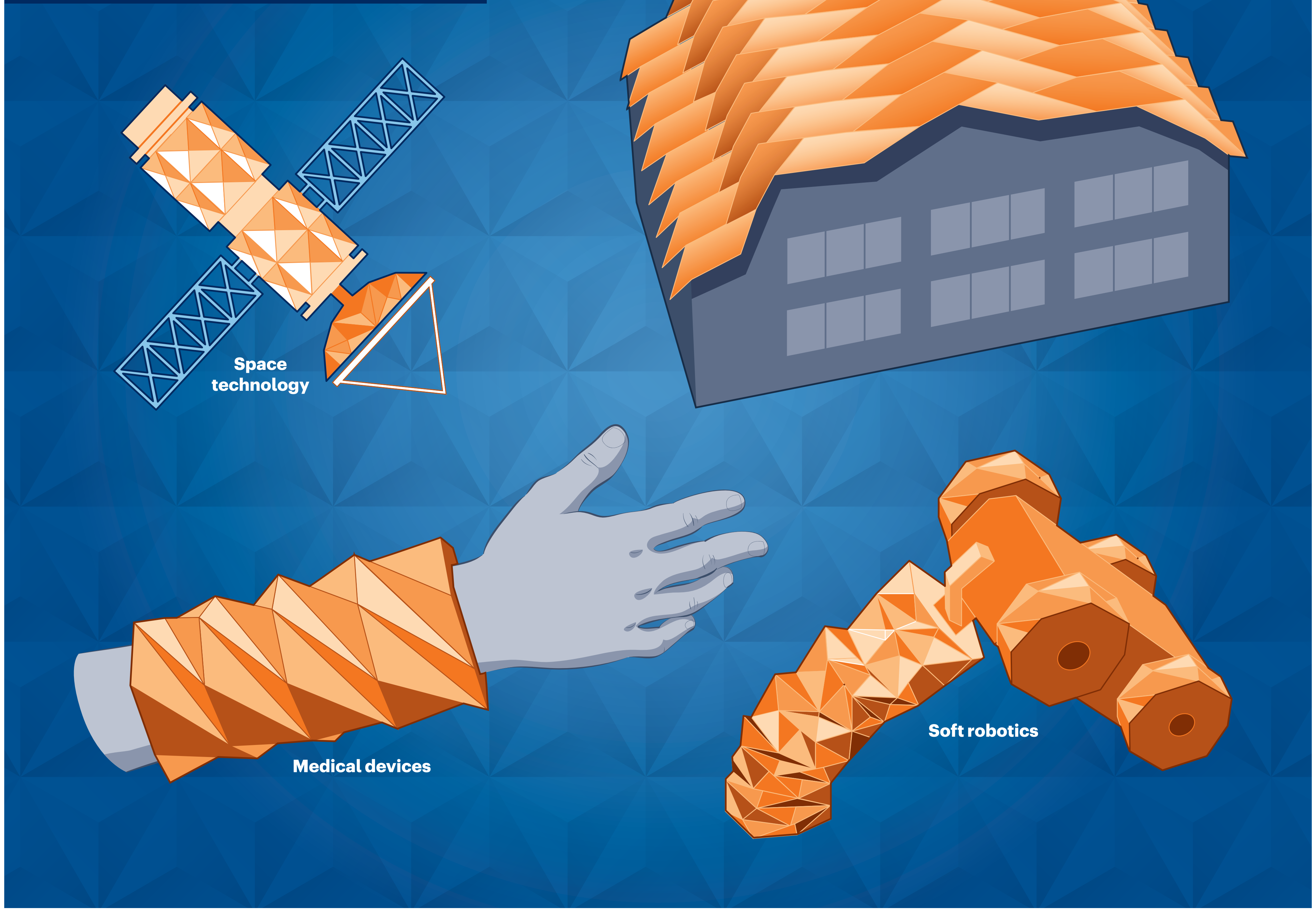
Origami patterns can be created by folding materials such as craft paper, cardboard and polyester or composite films. Folding lines are marked with evenly spaced cuts then perforated using laser cutters. Developable patterns, such as the Miura-ori, are made by folding a single sheet along creases, while non-developable patterns like the Eggbox require assembling multiple parts. Sample quality is crucial for experiment success. The sample's dimensions in the rest configuration serve as a common reference point for experiments, theory and simulations. Discrepancies between theory and experiment often stem from defects like ageing, manufacturing error or fatigue. Before any mechanical testing, samples should be visually inspected for pattern integrity and dimensions measured in the rest configuration. Various experimental set-ups may be required to study origami structures, depending on deformation and loading characteristics.

Results

Origami tessellations display tunable and programmable properties, owing to their various folded states. Through active stimuli, such as force, these properties can change. Important mechanical properties, such as Poisson's ratio, elastic bandgaps, thermal expansion coefficients and anisotropic stiffness, can be tunable in origami metamaterials. Origami structure configuration is characterized by its crease pattern and the dihedral angle between panels in the folded state. Configurational analysis of origami is carried out using spherical trigonometry to establish direct relations between dihedral angles at crease vertices and determine their degrees of freedom. The degrees of freedom for an entire origami structure, spanning multiple vertices, can be determined by applying compatibility constraints on the creases connecting adjacent vertices.

Applications

Origami engineering applications range from metamaterials and robotics to medical devices, achieving functions such as vibration control, mechanical computing and shape morphing.



Reproducibility and data deposition

The performance of origami structures' mainly depends on geometry, rather than the material used. Geometric imperfections can hinder foldability and increase compressive stiffness in origami structures. This effect is less noticeable with compliant materials, but more pronounced with rigid ones. Origami structures are usually shared in data formats that store meshes, which must include vertex coordinates and face grouping information. The flexible origami list data structure (FOLD) format, designed for origami not only stores static design data but also captures folding process frames, unlike standard industrial formats.

Limitations and optimizations

The behaviour of origami patterns is affected by geometric imperfections and material thickness. The presence of these can cause unexpected behaviour. Therefore, it is crucial to conduct extensive studies incorporating these imperfections to assess origami's suitability for applications. Manufacturing origami structures, particularly non-developable patterns, often relies on manual assembly. Exploring advanced methods like 3D printing may offer solutions to these challenges.

Outlook

Beyond modelling and manufacturing of origami, automated folding and actuation can lead to major advances especially with multi-physics considerations, for example magneto-mechanical actuation. Thus, origami engineering has potential for continued advances in several fields ranging from robotics to space structures, architecture and medical technology. As origami ideas permeate different fields, several origami modelling frameworks and computing packages are expected to be developed in the future.

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