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# Geometry of multi-state pop-up materials.

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## Abstract

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Kirigami & Origami, the Japanese art of paper cutting & folding, offer a powerful approach to fabricating complex geometric patterns from a single sheet of paper without adding or removing material. We integrate these two techniques by using both cuts & folds to create a pop-up material that provides the freedom to localize deformations at desired locations. By identifying the right cut and fold patterns, we can transform a flat sheet into three-dimensional shapes with few actuation degrees of freedom. To achieve this, we construct a pop-up unit with two straight cuts and three parallel folds orthogonal to the cuts on a flat sheet. This unit is then deployed by folding the sheet along its centerline, bringing the edges of the sheet together. By patterning a sheet with several pop-up cuts and folds at precisely computed locations, we demonstrate the transformation to a tessellated 3D shape upon deployment. We also show that one pattern of cuts & folds can be programmed to take multiple shapes at different deployment angles by employing the geometry underlying deployment. Using precision cuts on a sheet of paper we experimentally realize these materials and highlight their applicability in soft-robotics, architecture and biomedical engineering.

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