

# Local Actuation of Tubular Origami

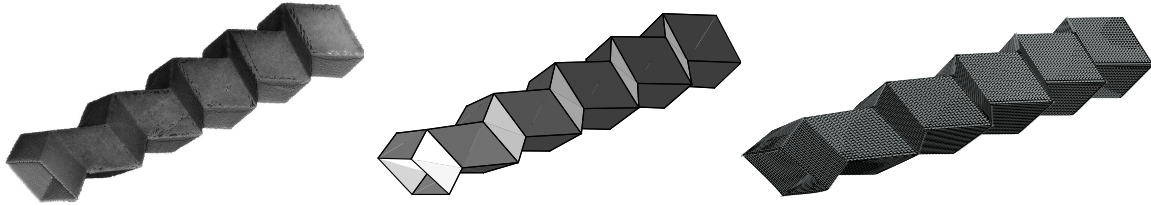
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## Abstract

Origami promises the ability to achieve three-dimensional geometry from flat sheets of material. An important mechanical behaviour to model is the response to local actuation and how this propagates through a structure; this is a crucial constraint to the design of origami-inspired deployable or morphing structures with embedded actuators.

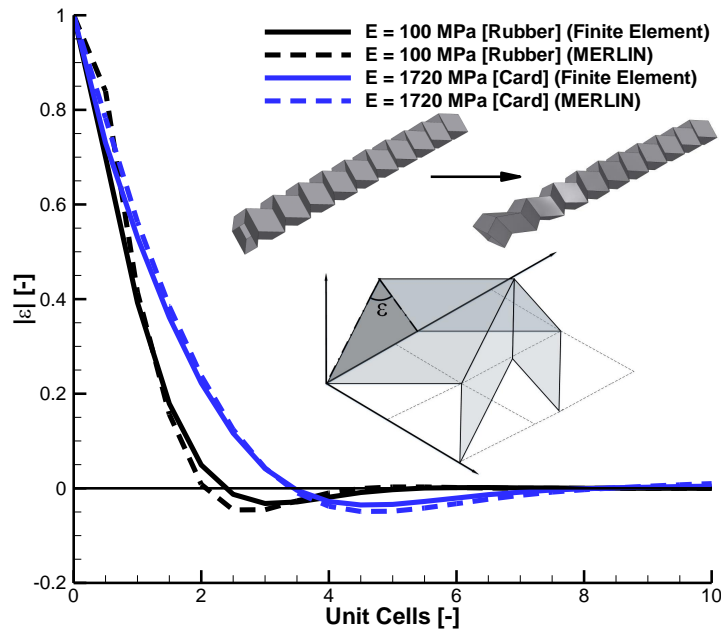
Rigid origami is the most top-level model of origami structures and has been used to describe the global behaviour of tessellated origami sheets. Rigid origami assumes that facets, the material between the folds, cannot deform. In this model a Miura-ori tube, which is the focus of our studies, only has a single degree of freedom (Filipov et al., 2015). This is not representative of how such structures behave physically, and instead any actuation will be localised due to elastic decay. Rigid origami has been extended by including another fold on the facets to capture the bending deformation. This has been implemented in a non-linear model, MERLIN (Liu and Paulino, 2017), which uses a pin-jointed framework to capture both out-of-plane and in-plane deformations. These additional folds mean that the structure is no longer modelled as a single degree of freedom system and localisation of actuation can be captured. Evans et al. (2015) derive a decay length for Miura-ori sheets using methods from lattice mechanics; this formulation implies that, for a given actuation, the decay length is dependent only on geometric parameters defining a unit cell.



**Figure 1:** A comparison of experimental point cloud (left), MERLIN (centre), and FEA (right) results for Miura-ori tubes.

The aim of this paper is to investigate the effect of structural properties on the decay of local actuation in origami tubes using experimental, analytical, and numerical methods. Experimental results are obtained using a 3D laser scanner to capture the deformed shape of origami tubes

as a point cloud and extract the geometric parameters that define a unit cell. Analytical results are obtained using the MERLIN model (Liu and Paulino, 2017), and numerical results using a Finite Element Analysis (FEA) with shell elements for facets and hinge elements for folds. Examples of the outputs of these are shown in Figure 1.



**Figure 2:** Preliminary results show that, in both the FEA and MERLIN models, the material properties affect how actuation, characterised by the angle  $\varepsilon$ , propagates through a Miura-ori tube. A fold stiffness of  $3 \text{ Nm rad}^{-1} \text{ m}^{-1}$  is assumed for all tests.

Preliminary results, shown in Figure 2, indicate that the material stiffness affects the decay length, which is also supported by experimental evidence. Furthermore, geometric parameters describing a unit cell may have different decay profiles, and do not follow an exponential decay. Finally, a new and unusual property associated with Miura-ori tubes has been observed.

## References

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