

Can origami be a source of innovation for science, engineering and architecture?

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Origami is the ancient art of paper folding. It started with traditional designs, then came to creation of new models, and more recently transpires into scientific applications and researches. One of the first topic deals with geometry; apart from being used for educational purposes, it raises non trivial questions, for instance: Can the perimeter of a flat-folded model be larger than the one of the original unfolded sheet of paper [Demaine et al 2008]? Given a crease pattern, will it fold flat [Bern et al 1996, Hull 2002]? Given a target folded state, can a folding sequence be designed automatically [Konjevod 2009, Demaine et al 2014]?

From these studies, the dedicated field of computational origami emerged since 1996, making use of algorithms for optimization and design [Lang 1996]. The folding process itself is linked to the kinematics of mechanisms [Bowen et al 2013] and materials [Dudte 2016]; it is also a source of innovation for designing deployable, foldable, and shape-adaptive structures: stents [Kuribayashi et al 2006], airbags, temporary roofs [Gioia et al 2012], compliant mechanisms [Francis et al 2013], spatial applications... Both these features and the artistic background of origami are also used for design of architectural structures.

The aim of this presentation is to give an overview of the synergy of origami and scientific topics [Dureisseix 2012], to illustrate its potential source of innovation, and to present recent advances in engineering field.

References

[Bern et al 1996] Bern, M. and Hayes, B., The complexity of flat origami, in: *7th Annual ACM-SIAM Symposium on Discrete Algorithms*, 175-183, 1996. ISBN 0-89871-366-8.

[Bowen et al 2013] Bowen, L. A., Grames, C. L., Magleby, S. P., Lang, R. J. and Howell, L. L., An Approach for Understanding Action Origami as Kinematic Mechanisms, *Journal of Mechanical Design* 135:111008, 2013. <https://doi.org/10.1115/1.4025379>

[Demaine et al 2008] Demaine, E. D. and O'Rourke, J., *Geometric Folding Algorithms: Linkages, Origami, Polyhedra*, Cambridge University Press, 2008. ISBN 9780521715225.

[Demaine et al 2014] Demaine, E. D. and Ku, J., Filling a Hole in a Crease Pattern: Isometric Mapping of a Polygon given a Folding of its Boundary, in: *Origami6: Proceedings of the 6th International Meeting on Origami in Science, Mathematics and Education – 6OSME*, 2014, preprint available at <https://arxiv.org/abs/1410.6520>

[Dudte 2016] Dudte, L. H., Vouga, E., Tomohiro, T. and Mahadevan, L., Programming curvature using origami tessellations, *Nature Materials* 15(5):583-588, 2016. <https://doi.org/10.1038/nmat4540>

[Dureisseix 2012], Dureisseix, D., An overview of mechanisms and patterns with origami, *International Journal of Space Structures* 27(1):1-14, 2012. <https://doi.org/10.1260/0266-3511.27.1.1>, preprint available at <https://hal.archives-ouvertes.fr/hal-00687311>

[Francis et al 2013] Francis, K. C., Blanch, J. E., Magleby, S. P. and Howell, L. L., Origami-like Creases in Sheet Materials for Compliant Mechanism Design, *Mechanical Sciences* 4:371-380, 2013. <https://doi.org/10.5194/ms-4-371-2013>

[Gioia et al 2012] Gioia, F., Dureisseix, D., Motro, R. and Maurin, B., Design and Analysis of a Foldable/Unfoldable Corrugated Architectural Curved Envelop, *Journal of Mechanical Design* 134(3):031003(1-12), 2012. <https://doi.org/10.1115/1.4005601>

[Hull 2002] Hull, T., The combinatorics of flat folds: a survey, in: *Origami3, Proceedings of the 3rd International Meeting of Origami Science, Mathematics, and Education – 3OSME*, 29–38, 2002, preprint available at <https://arxiv.org/abs/1307.1065>

[Konjevod 2009] Konjevod, G., Integer programming models for flat origami. In: *Origami4, Proceedings of 4th International Conference on Origami Science, Mathematics and Education - 4OSME*, chapter 18, 207-216. 2009. <https://doi.org/10.1201/b10653-22>, preprint available at <http://www.organicorigami.com/thrackle/papers/4osme.pdf>

[Kuribayashi et al 2006] Kuribayashi, K., Tsuchiya, K., You, Z., Tomus, D., Umemoto, M., Ito, T. and Sasaki, M., Self-deployable origami stent grafts as a biomedical application of Ni-rich TiNi shape memory alloy foil, *Materials Science and Engineering: A* 419(1–2):131–137, 2006. <https://doi.org/10.1016/j.msea.2005.12.016>

[Lang 1996] Lang, R. J., A Computational Algorithm for Origami Design, in: *Twelfth Annual Symposium on Computational Geometry*, 98-105, 1996, ISBN 0-89791-804-5. <https://doi.org/10.1145/237218.237249>