The Miura Fold: Origami in Action

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Origami, the traditional Japanese art of paper folding, is uniquely contributing to innovation in modern science and technology. Using origami techniques to fold materials to make complicated yet compact structures has become the prime focus of origami applications. One such application, the Miura fold, is a gamechanger in space, medical, industrial and electrical engineering design. The Miura fold, or "Miura-ori", is specially the methodology of folding a flat surface into a smaller area. The fold has use where a large flat structure needs to be compactly stored for transportation. The following figure, Figure 1: Miura Fold, highlights this engineering utility of the fold design, that is, the ability to flatten and condense larger, flat surfaces:

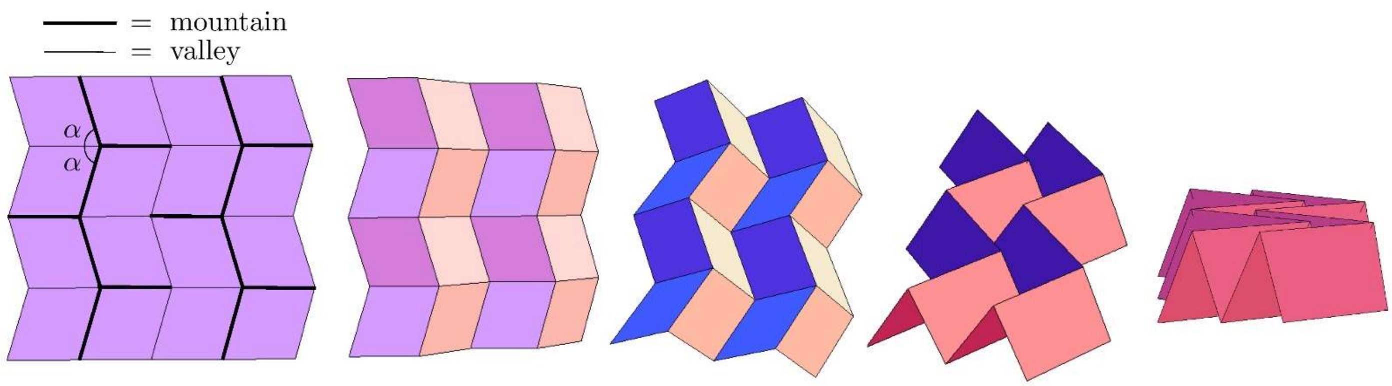


Figure 1: Miura Fold
(Sci Tech Cafe, 2018)

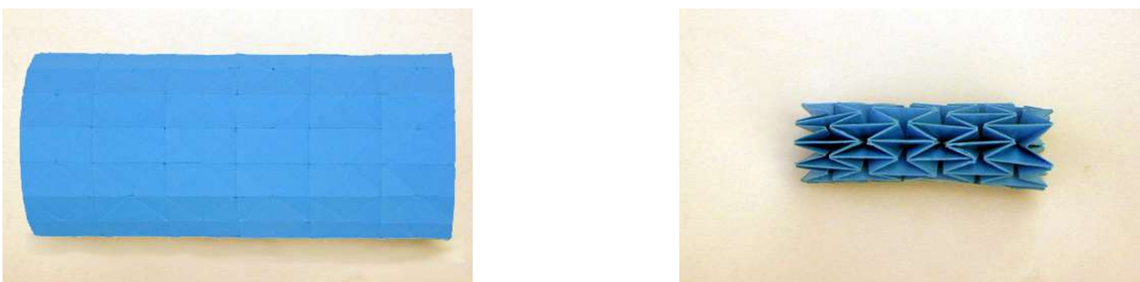
As shown in Fig. 1 above, the Miura fold uses of a form of tiled parallelograms that overlap each other in the fold to solve packaging issues in various disciplines. With valley folds and mountain folds alternating between creases, and each parallelogram being the mirror reflection of its neighbor across a crease, the Miura fold can be done in one continuous motion by pushing the opposite ends together and undone by pulling the same. Of note, the parallelograms that cover the entire portion of the flat surface without overlapping have angles determined by the flat surface's shape and size. Therefore, each Miura fold has a unique constitution but similar function.

Originally invented by Japanese astrophysicist Koryo Miura to efficiently store and transport solar panels in the 1996 Space Flyer Unit mission by Japan, the fold has revolutionized spacecraft design significantly. For example, researchers at Brigham Young University, National Science Foundation, NASA's Jet Propulsion Laboratory, and origami expert Robert Lang designed a space array which can be folded compactly and then deployed while in outer space (The Daily Universe, 2013). When opened, the proposed disk-like array is 25 meters in diameter (82 feet) but when folded origami-style, it is only 2.7 meter (8.8 feet) (The Daily Universe, 2013). The following figure, Figure 2: Origami inspired Deployable Solar Array, shows the rendering of the prototype array that uses Miura fold:

Figure 2: Origami inspired Deployable Solar Array
(The Daily Universe, 2013)

As shown in Fig. 2 above, due to the Miura folding technique, the solar panels are not only made compact for packing and transportation but also made to be easily mechanically unfolded for use. While the Miura fold was initially developed for the space engineering field, it has many creative applications in the present day.

Of note, Miura fold is also called the map fold, as one of its major applications has been to fold large sheets of map into a pocket-sized wad of paper. However, most recently researchers have been using this folding technique in various scenarios that need compact compression and easy expansion of any flat rigid material. For example, scientists at Arizona State University firstly manufactured a lithium-ion battery made of carbon nanotube-coated paper and subsequently applied the Miura fold to reduce its size and increase its energy density (Extreme Tech, 2013). Additionally, Harvard researcher Shawn Douglas was able to use origami on DNA to create clam-like cages, called nanorobots, that only open to targeted cells in the body (New Scientist, 2012). This consequential invention has been used to locally administer cancer drugs, thus reducing the risks associated with cancer treatments (New Scientist, 2012). Moreover, in 2003, Zhong You and Kaori Kuribayashi from the University of Oxford developed an origami stent which may be used to enlarge clogged arteries and veins (Origami Resource Centre, 2018). The following figure, Figure 3: Origami Stent (a) Open and (b) Folded, shows the medical utility of origami techniques:



(a) (b)

Figure 3: Origami Stent (a) Open and (b) Folded (Cabinet, 2005)

With the aforementioned applications, Miura fold is evidently a promising invention for industrial, pharmaceutical and biomedical engineering. Furthermore, the Miura fold also has potential for simple, daily-life usages. A team of Harvard researchers under L. Mahadevan, the Lola England de Valpine Professor of Applied Mathematics, Organismic and Evolutionary Biology, and Physics at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS), developed an algorithm that can create certain shapes using the Miura fold, repeated with small variations (Science Daily, 2016). Given the specifications of the target shape, the program lays out the folds needed to create the design, which can then be laser printed for folding (Science Daily, 2016). Researchers promise the applicability of these Miura fold variations to building foldable furniture and other small-space living requirements.

Conclusively, the Miura fold is a brilliant mathematical and geometrical innovation that holds the potential to advance many technological endeavors of humanity. Decades since its invention in 1985, the fold continues to provide new avenues for achieving engineering design minutiae without sacrificing structural integrity. The future appears a more technologically sophisticated place in the presence of the Miura fold.

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