Recent advancements in ORIGAMI

[1]Dipa B. Thummar, [2]Mehul H. Kantaria

[1]ME Graduate, [2]Assistant professor
[1]ECE, Atmiya Institute of Technology & Science, Rajkot Gujarat
[2]ECE, Marwadi Education Foundation's Group of Institutions, Rajkot

***Abstract*— Origami, the traditional Japanese art of paper folding, has remained popular over the centuries because it enables the production of various three-dimensional (3D) sculptures simply by folding two-dimensional (2D) sheets. In recent years, structural engineers and bio-engineers have been inspired to harness these origami folding techniques for a range of technological applications, including the fabrication of solar panels for space deployment, flexible medical stents, and nanoscale DNA-based objects, leading to the development of a new discipline, "origami engineering". This paper covers various types of origami and recent advancement in origami techniques and applications.**

***Index Terms*— Origami, Advancement, latest origami structures, Origami applications and types of origami**

I. INTRODUCTION

Today, origami is popular all over the world as a universal play activity involving folding a sheet of paper. There are a lot of traditional folding descended from forerunners. On the other hand, origami has been a target of mathematical researchers. As the result, now we have the knowledge to design such complicated origami works that we could not a few decades ago. At heart is the mathematics behind the humble piece of paper, which was studied as early as the 1930s. The mathematics gives rise to challenging unsolved problems and software that design complex origami on-demand.

The art of making paper from pulp originated in China in the year 102A.D. Paper then became more available to the masses. The secret of making paper was kept in China for several hundred years and finally made its way through Korea and into Japan. A Buddhist monk is said to have carried this secret. The introduction of paper making to Japan several hundred years later coincided with the development of their religion and soon became part of the lives of its people. Colours and silk threads were added and origami was held in high esteem. Gifts were decorated with "noshi." Noshi had particular fold patterns depending on the gift.

In Japan, at one time origami was taught in schools but today, children are generally taught origami at home. Holidays are celebrated with colourful origami decorations made by the family. On children's day (formerly boy's day), children make colourful carp: a fish that swims upstream, against the current. This symbolizes strength. During the summer, Tanabata, The Star Festival is celebrated. Live bamboo branches are decorated with origami stars and other paper decorations in a manner which brings to mind a decorated Christmas tree.

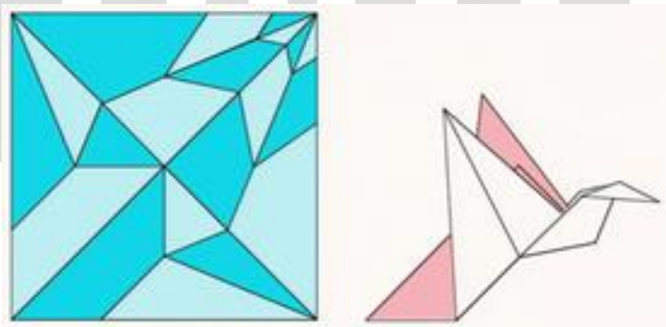

Fig. 1 Crease pattern of a flat-folded bird [17]

II. TYPES OF ORIGAMI

Realistic: Creations that exhibit the main features of the subject, often resulting in complex designs with many steps.

Minimal: Creations that capture the essence of the subject with minimal folds and with an emphasis on simplicity.

Modular: Multiple geometric "units" made from multiple sheets of paper whose flaps and pockets tuck into each other to form polygons or polyhedra. Typically, all sheets are folded in the same way or in a small number of ways.

Composite: As with modular origami, multiple sheets of paper are used, but in this style each sheet is folded differently to realize a different part of the subject. Composite origami was one of the most common styles in the 1950s and ’60s but is relatively uncommon today.

Practical: Models that have a real-life application, such as for use as envelopes, boxes, cups, dishes, etc.

Pureland: A concept suggested by John Smith of England, who proposed a composition system using only square paper and “mountain” and “valley” folds, resulting in models that are easy to duplicate.

Tessellations: A geometric folding technique in which the image is created by the pattern of folded edges across the paper. Tessellations are often periodic (repeating) and may be flat or three-dimensional, and many of them exhibit further structure when held up to the light. Not surprisingly, many of the leading practitioners of this technique have been mathematicians.

Wet folding: A technique invented by Akira Yoshizawa in which the paper contains a water-soluble glue (known as sizing) and is dampened slightly before folding. The dampness permits the paper to be folded into soft curves, which then harden in durability as the paper dries.

Crumpled: A technique created by Paul Jackson and developed by Vincent Floderer that involves the crumpling of the paper before folding. This technique can produce highly realistic organic forms.

III. ADVANCEMENT IN ORIGAMI

The uses of origami are not confined to artistic expression. Insights from folding paper have been applied to space technology, automobiles, medicine and programmable matter; these applications began to appear a few decades ago. Several technological products have been based on origami. These devices are flat and sheet-like, and they need to change their shape often, so that they can be stored and transported compactly but expand to full size for usage. The reversible folding motions of a sheet make origami the perfect answer. USA’s National Science Foundation has recognized this potential, giving USD14M of awards to projects related to “Origami Design for Integration of Self-assembling Systems for Engineering Innovation (ODISSEI).”

The software ORI-REVO was developed for the purpose of exploring new origami figures by using a computer. The shapes generated with ORI-REVO are based on the surface of revolution. Shapes which have curved surfaces are also designed with this software. The shapes include that of several artworks known as Chris K. Palmer’s PolyPouches, Jeannine Mosely’s Bud, and Robert J. Lang’s Rimpot which are helpful for further development of origami applications.

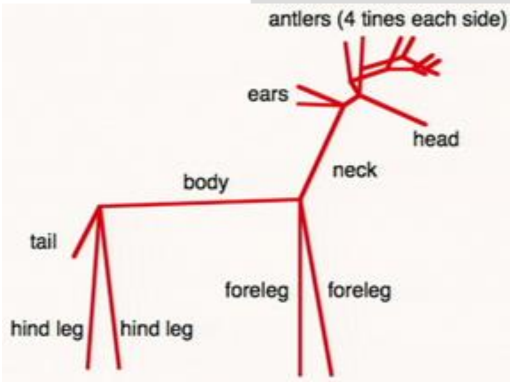

Fig. 2 Stick figure representing the subject [16]

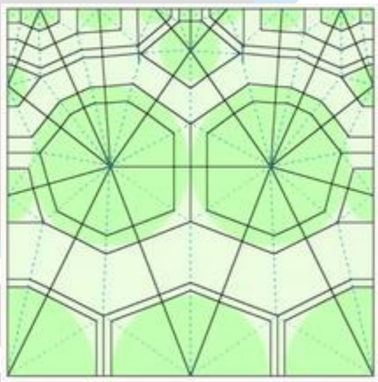

Fig. 3 Crease pattern ("folding instructions") [16]

Fig.4 Final folded product [16]

Robert J. Lang developed the mathematics needed to generate a pattern of lines that folds into a specified stick figure, automating the design of animal origami.

In 1955, Japanese scientists used an origami technique, the Miura map fold, to fold the huge solar panels of a satellite into a small package. After the satellite entered space, the solar panels unfolded to full size and functionality. The method of folding is called "Miura-ori".

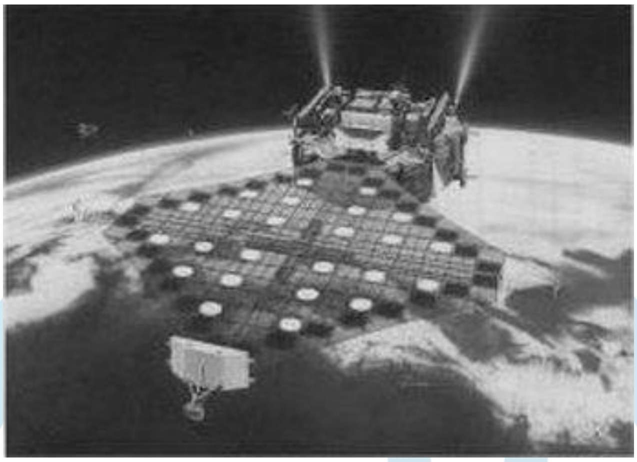

Fig. 5 Solar Panels for a Satellite [13]

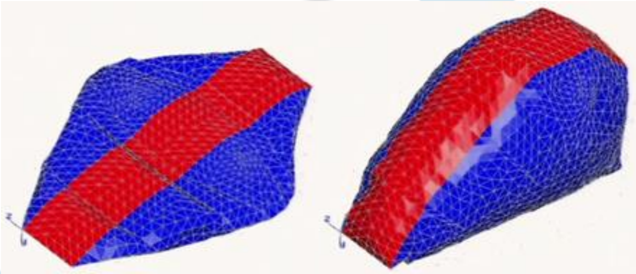

Fig. 6 Airbag Simulations [14]

To ensure that the airbag of a car will inflate properly when it crashes, copies of the car will often need to be crashed in real life. However, modelling the folding surface of the airbag using origami allows engineers to replace real crash tests with computer simulations.

In the area of microfabrication, origami folding strategies have also proved to be promising approaches for producing 3D microstructures since they are simple and time-effective compared to other 3D microfabrication techniques such as stereolithography and laser micromachining. In particular, the origami folding techniques have recently been explored to produce various 3D cell-laden microstructures including micro-sized containers and scaffolds for artificial tissues. The folding of these microstructures is typically performed by surface tension, stress-induced forces, and shrinkage of the hinges with external triggers such as temperature and electrical/chemical signals. However, such driving forces require functional materials that involve complicated preparation processes. In addition, the compatibility of the external triggers to living cells must be considered in these folding mechanisms [20].

Researchers from the University of Oxford developed an origami stent graft, a tube-shaped medical device used to hold arteries open during surgery. The metal tube would be folded into a thinner shape using a special origami pattern. It would then be inserted into an artery, where body heat would cause it to unfold and expand, holding the artery open.

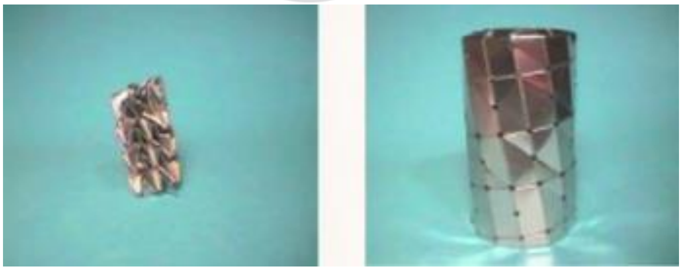

Fig. 7 Origami stent graft [15]

The Eyeglass is a foldable telescopic lens designed by Robert Lang which can be easily packed into a space shuttle Space Telescope, Eyeglass and deployed when in space by utilizing origami principals and techniques. The origami structure shown in Fig. 4 is called the “Umbrella” structure after its resemblance to a collapsible umbrella, which was scalable and had mass-producible parts.

A foldable grocery bag from steel was built by Zhong You and Weina Wu using origami-inspired design as shown in Figure. It allowed shopping bag built from a rigid material or an open-topped cardboard box could be folded flat without having its bottom opened. This approach could help speed up factory automated packaging processes. The ultimate dream of the designers is to make rigid building that could be reconfiguredin the future.

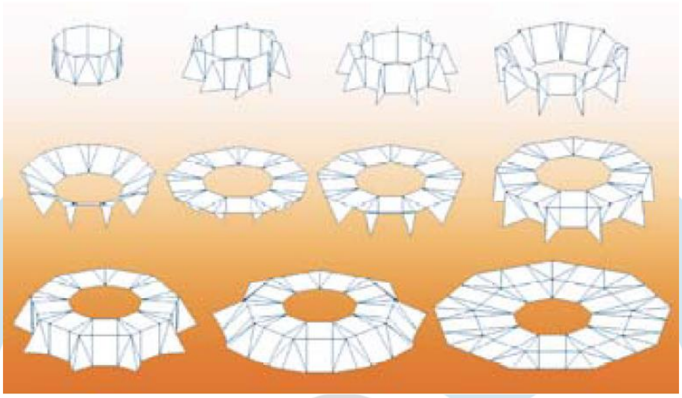

Fig. 9 The Eyeglass can be folded from a flat disk [18]

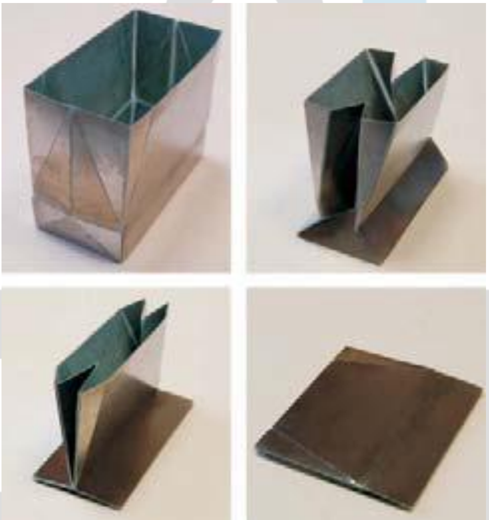

Fig. 9 Origami Grocery Bag [18]

A technique was developed by Michael Dickey where polymer sheets self-fold when exposed to light as shown in Figure. Polymer sheets were run through a desktop printer to get a pattern of black lines, or crease pattern in origami, and they automatically fold along the black lines when exposed to light. The concept is such that black absorbs more energy than other colours and thus black lines will shrink faster than other areas.

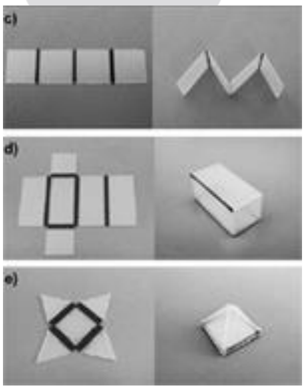

Fig. 10 Polymer sheets with black lines [18]

IV. CONCLUSTION

This paper has presented the fundamentals of Origami science, Rigidorigamiand some of its applications. It is in hope that one could gain more insight about origami technology and apply it in every possible area for sustainable utilization of space and weight.

REFERENCES

[1] Vishal Sorathiya, Hardik Dhamecha, S. Srinath Kashyap and Shobhit K Patel, "PixelOri Painting" in Mumbai Patent Office, India, App. No. 201721011337, 2017

[2] Developing unique origami-shaped antennas (2013, October 1) retrieved 15 November, 2017.

[3] Juan Yan, Chongya Hu, Xunwei Liu, Jian Zhong, Gang Sun and Dannong He, "Recent Developments of New DNA Origami Nanostructures for Drug Delivery", Current Pharmaceutical Design, Volume 21 , Issue 22 , 2015.

[4] Origami Science. [Online] https://www.origami-resource-center.com/origami-science.html

[5] Razca paper craft, "How to make 3d Origami rose painting", Published on Sep 28, 2013. [Online] https://www.youtube.com/watch?v=svokSaFi7kg

[6] Emilio Costanzo, "The monna lisa in origami 3d emilio, la gioconda", Published on Jun 30, 2014 . [Online] https://www.youtube.com/watch?v=UdeskXRzn8M

[7] Emilio Costanzo, "Madre teresa di calcutta origami 3d emilio mother teresa of calcutta origami 3d hd emilio", Published on Feb 2, 2016. [Online] https://www.youtube.com/watch?v=tDkNlEeBUiA

[8] Zhifu Xiao, Robert Bosch, Craig S. Kaplan and Robert J. Lang, "Modular Origami Halftoning: Theme and Variations," in Proceedings of Bridges 2015: Mathematics, Music, Art, Architecture, Culture, Kelly Delp, Craig S. Kaplan, Douglas McKenna and Reza Sarhangi, eds., Tessellation Publishing, 2015, pp. 61-68.

[9] Meher McArthur, "Folding Paper: The Infinite Possibilities of Origami Educator Guide", International Arts and Artists, Washington, D.C., April 27, 2014

[10] Helena Verrill. "Origami tessellations". R. Sarhangi, editor, Conference Proceedings of Bridges: Mathematical Connections in Art, Music, and Science, pages 55{68, 1998

[11] Fei, L.J. and Sujan, D. (2013). Origami theory and its applications: A literature review. Int. J. Soc. Hum. Sci. Eng.. 7. 113-117

[12] N. Kishi and Y. Fujii, "Origami, folding paper over the Web," *Proceedings. 3rd Asia Pacific Computer Human Interaction (Cat. No.98EX110)*, Shonan Village Center, 1998, pp. 337-342.

[13] Solar Panels for a Satellite [Online] http://www.herngyi.com/uploads/2/3/1/7/23170532/586195.jpg?345

[14] Airbag Simulations [Online] http://www.herngyi.com/uploads/2/3/1/7/23170532/5971845.png?221

[15] Origami stent graft [Online] http://www.herngyi.com/uploads/2/3/1/7/23170532/7178904.png?349

[16] ORI-REVO [Online] http://www.herngyi.com/uploads/2/3/1/7/23170532/7557186.png?286

[17] Crease pattern of a flat-folded bird [Online] http://www.herngyi.com/uploads/2/3/1/7/23170532/8161862.png?277

[18] L. J. Fei and D. Sujan, "Origami Theory and its Applications: A Literature Review", World Academy of Science, Engineering and Technology International Journal of Humanities and Social Sciences Vol:7, No:1, 2013