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Three-Dimensional Transformers

Origami is a traditional Japanese art form where artists create different three-dimensional shapes through the folding of a material. To develop a completely new three-dimensional object an artist must, to some degree, use trial and error. At the same time, I am sure that experienced origami artists have a tool box of folds they have used in the past that helps them create the object they envision.

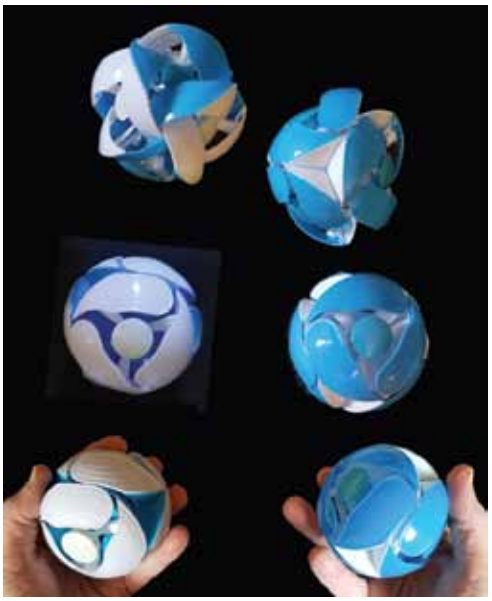


Photo 1—A simple toss into the air causes this ball to shape shift to change its color.

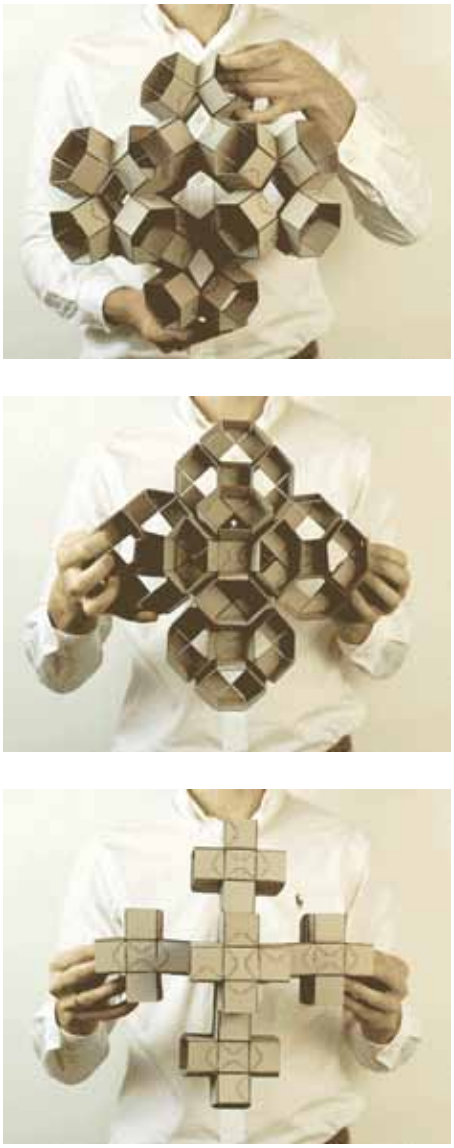
Using a modern process reminiscent of origami, the ball shown in Photo 1 will change its colors when it is tossed into the air. The acceleration created by a simple toss causes a slight air pressure differential on the top and bottom of the outer leaves of the ball. This causes its multiple thin plastic outer leaves to lift open and then switch their location with the inner leaves of the ball. To show you how this physical change takes place I captured a rapid series of snapshots which froze some of the physical movements of the ball during its metamorphosis from white to blue.

Professor Katia Bertoldi and her team of researchers at Harvard University's School of Engineering and Applied Science (SEAS) have recently developed a mathematical transformational technology that completely automates finding the best way to form a flat material into a form that can be shape shifted to perform many different functions. Using this technology, a designer or engineer would provide all the size and shape parameters that are needs to be achieved when the object transforms from one shape into another.

The computer algorithm that the Harvard researchers created applies a tool box of mathematical rules that it has at its disposal for creating all kinds of geometrical shapes. The program quickly finds all the possible solutions and then selects the solution that conforms to the parameters of size and shape that the researchers want as an output.

Photos 2-4 show an object that they created to show how multiple physical changes can be imbued into one object by their computer algorithm's knowledge of the mathematics of physical shapes. Hypothetically using this technology, you could create a habitat for astronauts that folds down flat to be transported on a flight to Mars. It can also be used to create a medical device that is so small it could be fed into the human body through veins, arteries, or the smallest of incisions. Once the medical device is in the correct position it can be opened to meet the medical needs of the patient. The next generation rescue robot could fold flat to sit in an emergency vehicle until needed; once opened, it can still shape shift to slip into an impossibly small opening to get to survivors.

It is truly amazing how their technology can alter the outer form of



Johannes Overvelde Harvard SEAS

Photos 2–4—These images all show the same object that can shape shift to change its form. By pre-designing the physical changes into an object, it can perform multiple functions or just change its size and shape.

Johannes Overvelde Harvard SEAS

Photo 5—The two metamaterial objects in this photo look different but they are the same object. They were created using the new Harvard technology so they can shape shift. By building in this ability this metamaterial can shift its functional properties.

large objects but that was not what they started out to accomplish. Their research goal was to develop the ability to change the outer form of a metamaterial (Photo 5). The physical shape of a metamaterial on a nano scale allows these materials to manipulate light and sound. Scientists have already shown with the right outer shape a metamaterial shrinks in size when it is heated and with a different outer form the metamaterial can actually cloak an object so light passes around it making the object invisible.

In the end, their transformational technology is equally successful at transforming the outer form of a material regardless of its size. Their technology breakthrough can be applied to everything from tiny nano-sized metamaterial structures, to structures as large as buildings and bridges. The breakthrough is very important because it will allow a design engineer to easily develop either full products or sub-assemblies that can be small for shipping and then open to full size once they are delivered to where they need to go. Watch this YouTube Harvard video for some further insight into this technology: https://youtu.be/7A_jPky3jRY.

Taking It a Step Further

1. In what way is the transformation of the ball in Photo 1 using the same principle that makes it possible for an airplane's wing to create lift?

2. Are Sir Isaac Newton's three laws of motion applicable when one analyzes the motion of the ball in Photo 1? Describe how they do or don't apply.

3. Metamaterials are barely covered in this column. They are the perfect subject for student research. They were actually discovered in the 1940s but research into their properties has recently exploded.

Alan Pierce, Ed.D., CSIT, is a technology education consultant. Visit www.technologytoday.us for past columns and teacher resources.