Origami structures as a possible solution for privacy concerns in evacuation centers

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Many natural disasters occur every year around the world, and frequency and intensity of disasters seem growing due to global warming. In 2019, two strong typhoon struck the east area of Japan, and the second one, Hagibis, was the deadliest typhoon to strike Japan since Typhoon Tip in 1979. In 2021, deadly floods swept through western Germany and parts of Belgium. These floods rank as the most destructive natural hazard in Northern Europe.

The condition of the people in disaster areas is quite appalling. Some residents are forced to evacuate and live in evacuation sites, usually with little privacy. In the sites people must sleep on the floor of a school gym without partitions, and it is difficult to hang out laundry and change clothes. Also, roads are often heavily damaged, which makes rescue operations and support to the affected areas extremely difficult. Earthquakes and heavy rains usually cause depressions of roads, and people and cars can't pass along such roads.

We may be able to overcome these poor conditions by using technologies of the Japanese art of paper folding: origami. The technology which we use is the features of origami balloons.

After some steps of folding paper to make an origami balloon, you will get folded paper with a small hole in the bottom. By blowing air into the hole, the paper is deployed and have a balloon-like shape (if you want to know how to make an origami balloon in detail, please google it).

The origami balloons have two features. One is inflatability: an origami balloon is very compact before inflation but occupy a relatively large volume after expansion. If you use 15 cm ×15 cm paper, you will get folded paper in very small size of 5 cm × 3 cm × a few mm before expansion. After you blow breath in the paper, it expands to 3 cm × 3 cm × 3cm. The other characteristic is bistability: origami balloons have two stable configurations—one compact and one expanded. In other words, the origami balloons don't snap back to the flat shape spontaneously and maintain the expanded form without constant input of pressure. Thanks to this feature, an origami balloon maintains its inflated shape even when some part of the paper is cut apart after expansion. To fold the expanded origami balloon back to the compact shape, you have to depressurize the interior of the origami balloon, for example, by pressing the side faces of the origami balloon inward.

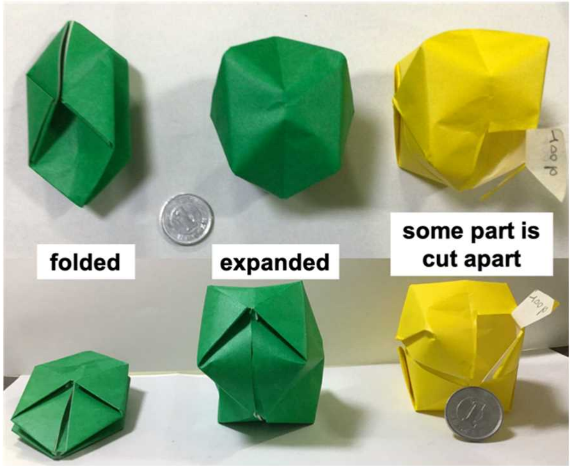

Figure 1. Origami balloons. Left: in folded shape. Center: in expanded shape. Right: in expanded shape. Some part of the paper is cut apart after expansion.

Thanks to these two features, origami balloons can be considered as a possible alternative to the tents in the evacuation sites. Imagine a big (meter-scale) origami balloon with some part cut apart to make a door, as in the right side of Figure 1. It could be used as a shelter in the evacuation sites. We could expand it only by blowing air in it by air pumps. This process would take little time and little labor, and only one or two persons would be necessary. In addition, it would not get deflated by itself because of bistability. Furthermore, at normal times it occupies very little space.

An attempt to design such inflatable and bistable structures was made by researchers in Harvard John A. Paulson School of Engineering and Applied Sciences in Cambridge [1]. The researchers found that inflatable and bistable origami-like structures can be realized by combining triangular facets in some specific ways. For real-world applications of their findings they designed and built some meter-scale structures with inflatability and bistability out of thick plastic sheets, one of which is a meter-scale inflatable shelter with tent-like shape. This structure can be completely flat to occupy a space of 1 m × 2 m × 0.25 m, so it can be stored in very little space and carried very easily. When an input pressure is provided by an air compressor, the structure expands to a shape of 2.5 m × 2.6 m × 2.6 m, so it is large enough for a parent and a small child to sleep together in. The structure has a door that can be opened without impacting structural integrity, so the internal space is accessible as living space which protects evacuees' privacy. Furthermore, this shelter can be easily folded back to the flat configuration by sucking air out with a vacuum. This feature may help people to come back to a normal life, because evacuation sites are usually used for other purposes at normal times. Therefore, this shelter may be able to solve the privacy concern in evacuation sites.

We may also be able to make use of inflatable and bistable origami structures in other ways. For example, we may bury inflated origami blocks in holes which gaped open in roads after earthquakes. This may possibly be helpful for restoring damaged roads quickly because folded origami blocks are very easy to carry.

In these ways origami structures may be very useful for preparation for disasters.

Recently the risk of natural disasters such as floods and heavy rains are growing due to climate change, and huge earthquakes also occur regularly around the world. We have to prepare for such disasters by every possible means, including technologies of origami structures.

References

[1] D. Melancon, B. Gorissen, C. J. Garcia-Mora, C. Hoberman and K. Bertoldi. Multistable inflatable origami structures at the metre scale. Nature. **592**, 545-551 (2021).