

A Novel Origami-inspired Foldable Model with Thick Panels

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Abstract

In most research on origami, it is assumed that the sheet has zero thickness. However, the thickness of the surface materials cannot be neglected when origami is used for deployable structures such as solar panels, retractable roofs or space antennas. Several methods have been proposed in the past to deal with the thickness of the sheet materials including the axis-shift method [Tachi 11], the offset panel technique [Edmondson *et al.*15], spatial mechanism approach [Chen *et al.* 15], doubling creases method [Ku and Demaine 15] and utilization of compliant mechanisms [Pehrson *et al.* 16], to list just a few. All of these methods have their advantages and limitations. For instance, some would result in surfaces that are not completely flat or with widened and flexible creases.

It is also noticed that for some applications where thick and rigid surface materials are used, the most critical requirement is that the surface must be flat without any gaps in its final expanded configuration. During the folding process and when the structure is packaged, it is unnecessary that all the panels are connected by line hinges. Solar panel belongs to one of such structures. This prompts us to examine whether folding of thick rigid surfaces could be done more conveniently by removing some line hinges. In other words, we try to use an approach based on kirigami to fold thick panels, which is the focus of this paper.

Our approach is best illustrated using the example shown in Figure 1(A). This is a folding pattern consisting of two degree-4 vertices. We place line hinges on the top and bottom surfaces for the mountain and valley creases, respectively. Then we cut open the horizontal crease. In this case, the folding pattern consists of a total of six thick panels. These panels are interlinked by hinges forming a spatial $6R$ linkage should it be foldable. In this particular case, it can be modeled as a $6R$ -Bennett linkage. To facilitate the complete folding process, it is also important to ensure that no collision of panels occurs during folding, and the panels can be folded packaged flat. The folding simulation shows that both of the conditions are met.

The advantage of this approach is that there is no need to either widen the creases or varying the thickness of the panels. Only conventional line hinges are used on the surfaces of the panels.

This is an on-going project, and we are working on more complex folding patterns which would require more cuts. After all the cuts are made, we shall then model the structure as nested spatial linkages, which are commonly overconstrained. Not only shall we ensure that mobility exists

in such structure, but we are also concerned with the compact folding of the entire surface. We shall report our results in the full paper.

We hope that our findings could provide a new simple and practical solution to the thick panel folding problem.

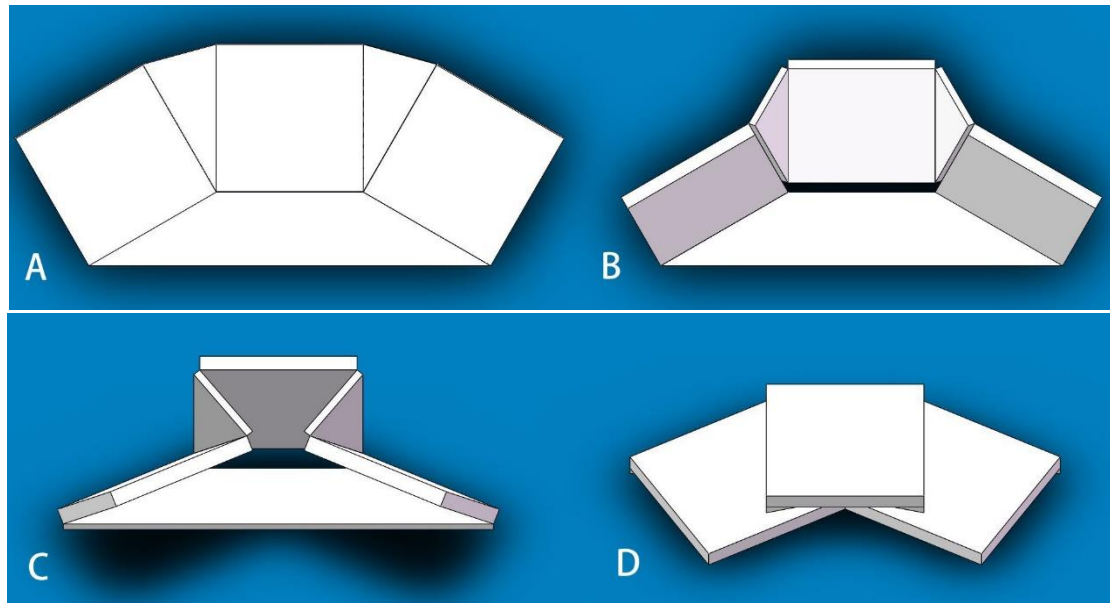


Figure 1: A. Origami pattern consisting of two degree-4 vertices. At each vertex, tsector angles are $\pi/6$, $\pi/2$, $\pi/6$, $\pi/2$, $5\pi/6$, and $\pi/2$. B – D. The folding sequence of a model made of thickness panels.

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