

# Crease Pattern Simplification for Automatic Folding

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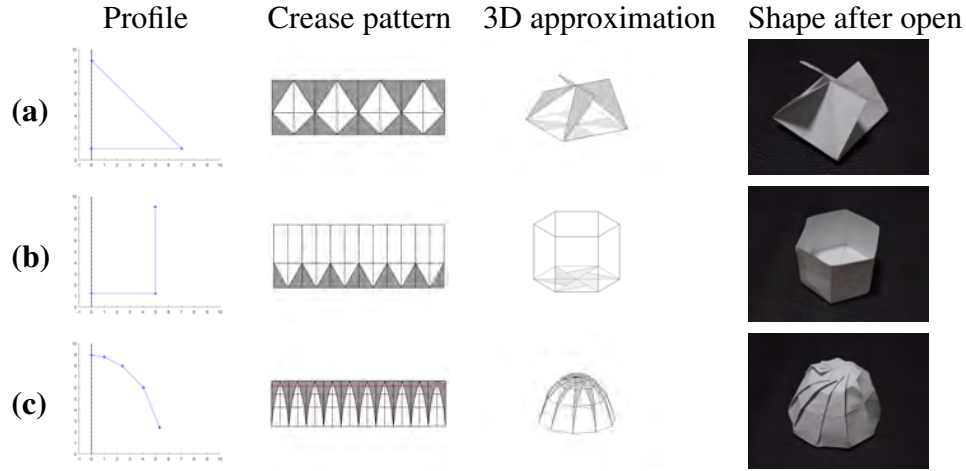
## Abstract

Now at day origami, the ancient art of paper-folding has attracted the attention of the scientific community, due to its applications in a vast number of fields, such as: air-spatial panels, medicine, architecture, and packaging. Be able to do automatic paper-folding using a robot has been a challenge for almost 20 years. There are two main problems with applying automation into a paper-handling process. The first of them, is how to handle fragile material such as paper without exerting excessive stress, i.e. how to handle it safely and reliably. The other problem is how to control deformation of objects that has infinite degrees of freedom using a finite number of manipulated variables. This paper centers its attention in the second problem and shows a solution to reduce the required manipulations by simplifying the crease pattern in order to be folded by a robot.

For a human being, that has a complete system of censoring such as the eyes, and the tactile feeling, apart of a pair of hands, can create three-dimensional (3D) origami figures, in many occasions very simple. On the other hand, for a robot, that has a limited number reachable movements and censoring, the difficulty of the crease patterns of these 3D shapes, plays an important role on which figures this robot could make and which not.

The origami patterns developed with previous software, are intended to be assembled by hand, and have folds that are very difficult to execute with a robot due to handling problems. In [Romero et al. \(2017\)](#), a crease pattern design methodology was proposed to create 3D shapes based in surface of revolution proposed in [Mitani \(2009\)](#) and able to be folded by a robot. This methodology uses a combination of simple folds with gluing segments to simplify the crease pattern. In this methodology, the crease patterns is created from a two-dimensional (2D) profile, that is divided into  $K$  number of equal segments, and rotated by  $2\pi/N$ , from 0 to  $2\pi$ . The resulting pattern, are two sets of trapezoids, one of them are the base panels that forms the final 3D shape, and the other ones are the resulting gluing flaps. Although this methodology can be used to build interesting 3D shapes (see [Fig.1](#)), it is limited to only figures based in surface of revolution.

In this paper, a novel methodology to design crease patterns for non-regular shapes is proposed. This methodology is extracted from the surface of revolution methodology, but instead of having a single profile, we have two or more. The profiles are extracted directly form a .STL file



**Figure 1:** Result profiles, patterns and 3D shapes using surface of revolution. (a) Pyramid , (b) Hexagonal box ), (c) Dome.

and used to create the crease pattern. The method uses the spatial information of the location of the vertices to perform a triangulation, preserving the cylindrical projection, that is required to generate symmetrical gluing areas, and needed by the robot to perform an automatic folding.

Several examples are shown to demonstrate the reliability of this crease patterns. Apart of this, a general solution is exposed to applying this methodology to any type of shapes. This methodology not only can be used to perform automatic folding, but also can be used to simplify complex crease patterns to be made by hand, and reduce the time to create these shapes.

## References

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