

A Transformable Theatre Design using Rigid Origami and Scissor Units

N. Akram, S. Krishnan

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Abstract

Some successful applications of origami and other scissors-based folding techniques in kinetic architecture and engineering have inspired and engaged more designers to do advanced research in this field. This paper discusses the design of a transformable theatre — an iconic feature of a Japanese Cultural Center in the University of Illinois Arboretum (a studio project). A combination of rigid origami and rigid scissor units are used to create a kinetic form that transforms from a slender tower to a broad canopy. The paper provides insights into the geometrical formulation of the structure, the kinematics of motion and structural stability. The detail of the interface between the origami superstructure and scissors-based sub-structure was critical to the success of the project as it had to be geometrically precise, mechanically reliable and structurally capable to carry the weight of the structure.

An egg-box pattern was chosen for its intriguing behavior of complete flat foldability along one direction (Fig. 1a). When expanded along one axis, the form curls inward along the perpendicular axis. Transformation from the closed hyperboloid tower (Fig. 1b) to an expanded shell form shading (Fig. 1c) offered a striking kinetic feature for the cultural center. In the undeployed state, the tower acted as a lamp in the landscape and in its deployed state it served as a shading canopy to the seating area of the theatre.

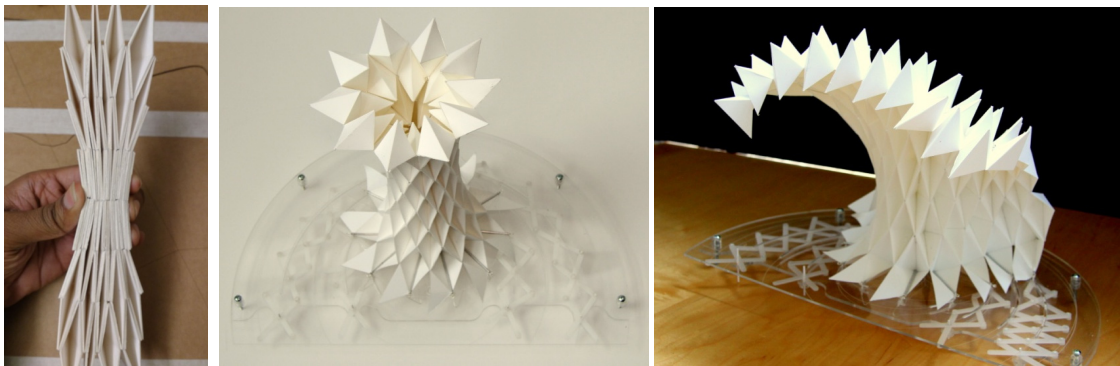


Figure 1: (a) Flat foldability of the egg-box pattern in one direction; b) Tower form in the closed or undeployed state; c) Canopy form in the open or deployed state.

It was intended to change its base configuration from circular to linear when deployed from the closed to open state. In order to guide the tower along a curvilinear path, a base mechanism was designed (Fig. 1b) so as to allow for the form to deploy without loss of overall structural stability (Fig. 2, top). Polar scissor units provided a geometrically and structurally logical choice to achieve the trajectory. Polar units deploy circumferentially and during the deployment process, the structure traces a segmented arch profile and the angle subtended by each unit of the segmented arch decreases with the increasing radius of the sector. In the fully deployed state, it would be a closed circular ring, and in the stowed state it will become a bundle of bar members (Fig. 2, bottom).

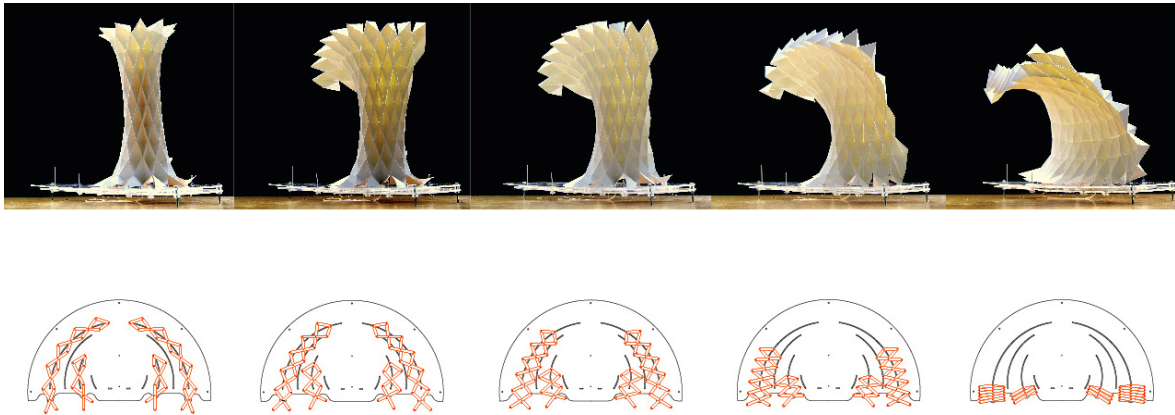


Figure 2: *Top*: Deployment sequence from the tower to canopy form; *Bottom*: Plan view of polar scissors mechanism to achieve a curvilinear path.

Due to the tower's slenderness and the relative flexibility during deployment to form the canopy, the form was stiffened using cables to control the deployment while keeping the structure stable at every step. The cables were optimally used so as to provide the necessary stiffness without overuse.